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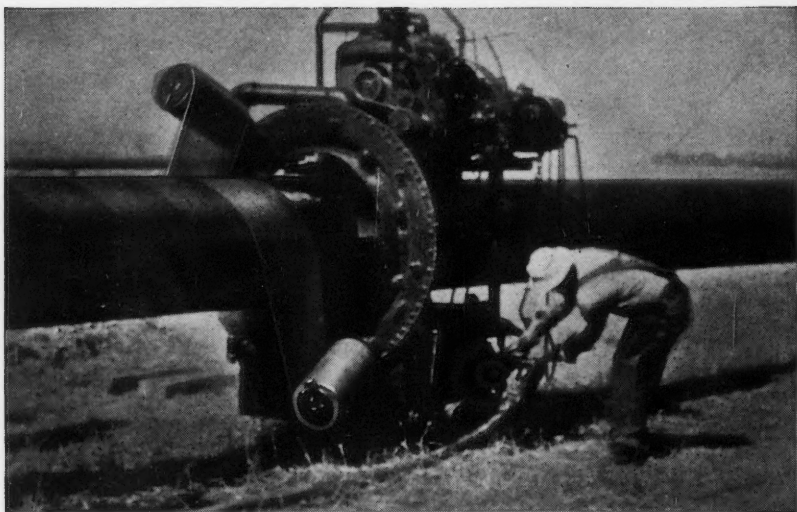


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THIS MONTH'S COVER

• *Drydocked by corrosion! Though this freighter, the Robert J. Collier, suffered little damage directly attributable to warfare, the enemy, corrosion, put her in drydock by eating away hull plates above the water line. The Marine Industry stages an unrelenting struggle against corrosion damage to floating equipment. The damage shown in the photograph can be attributed to pressure of war, which voided regular maintenance schedules. A symposium on Marine Corrosion is contemplated during the 1948 NACE Conference. Photograph courtesy the Port Houston Iron Works, Inc.*



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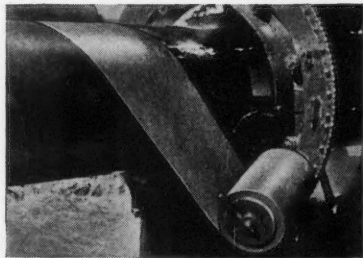
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A Survey of High-Temperature, Gas-Atmosphere Corrosion of Iron-Nickel-Chromium Alloys*

Part I

By James T. Gow*

THE SUPERIOR ability of Fe-Ni-Cr (iron-nickel-chromium) alloys to withstand static and dynamic stressing, and their physical and chemical stability at elevated temperatures, has resulted in their wide application as structural members in industrial furnace construction and as chambers and containers for chemical processes. The temperature range of application referred to extends above about 1400° F. to about 2200° F.

The high-temperature strength properties of the Fe-Ni-Cr alloys are generally given first consideration in making a selection of a desirable alloy composition. Equal consideration generally must be given to the surface scaling and subsurface corrosion to be encountered in the environment to which it will be exposed, to be assured of retention of this strength. Since economic considerations are also a factor, the selection of an alloy for a given application, therefore, involves striving for the optimum balance of strength properties and corrosion resistance

desired to arrive at a minimum cost per service hour.

On the whole, the requirements of the high-temperature industries are being quite successfully met at the present time by a variety of type compositions, within a wide expanse of iron, nickel, and chromium contents, knowledge of whose relative performance in numerous environments has been mainly gained by years of practical application. There are, however, many gaps in the present knowledge regarding the fundamentals involved in strength and corrosion resistance which need to be closed if the new and generally more strenuous demands being continually imposed by industry are to be met.

Continued effort is being put forth by the high-alloy producers and consumers in this country to gain increased fundamental knowledge of the high-temperature properties of these alloys. One outstanding example of their efforts is the researches sponsored on a cooperative basis at Battelle Memorial Institute by the 28 member companies of the Alloy Casting Institute, whose policy has been to disseminate the information gained through their bulletins and

* A paper presented at the Annual Meeting of NACE at Chicago, Ill., April 7-10, 1947.

* Assistant Supervisor, Battelle Memorial Institute, Columbus, Ohio.

the technical literature at such times as various phases of study are well enough advanced to be of practical value.

While the author is one of those identified with laboratory researches for the Alloy Casting Institute, this paper is a personal correlation of those quantitative data, so far available in technical literature, on the hot-gas corrosion behavior of the heat-resistant alloys, especially in air and flue gases.

The published quantitative hot-gas corrosion data are, for the most part, fragmentary and incomplete, and much more research needs to be done before a full understanding of the relative merits of various Fe-Ni-Cr alloy compositions in various gas atmospheres is obtained. This is especially the case as to the benefits, if any, to be gained by the introduction of additional elements. A brief discussion is, therefore, given of the procedures considered to be desirable for conducting tests, evaluating results, and reporting data to allow a satisfactory correlation of the results from various investigators.

The information brought together here is considered representative, but is not claimed to be complete.

Considerations of Importance Other Than Corrosion Resistance

Alloy Compositions

Fe-Ni-Cr alloys used for high-temperature applications are, for the most part, cast to form. The castings are made by the static sand mold method, the centrifugal method, and the precision casting process. Wrought alloy forms are also used, but to a much smaller extent.

Cast alloys are mainly of the simple Fe-Ni-Cr base, with controlled amounts of the minor elements, carbon, silicon, and manganese, which have important influences on the fluidity, strength, ductility, and soundness of the casting. Occasionally, substantial amounts of such elements as columbium, molybdenum, tungsten, cobalt, nitrogen, titanium, and aluminum are added for special purposes.

The limits of nickel and chromium contents, within which alloys with

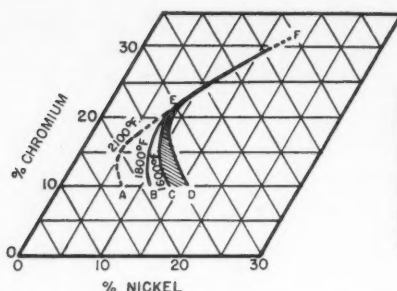
TABLE 1
A.C.I. Standard Designations of Alloy Compositions for Heat-Resistant Castings

No.	Designation	Nickel, Percent	Chromium, Percent
1.	HB	2 max.	18 to 22
2.	HC	3 max.	27 to 30
3.	HD	3 to 6	27 to 30
4.	HE	8 to 11	27 to 30
5.	HF	8 to 11	18 to 23
6.	HH	10 to 13	23 to 27
7.	HI	13 to 16	26 to 30
8.	HK	19 to 21	23 to 26
9.	HL	19 to 21	28 to 32
10.	HN	23 to 26	18 to 22
11.	HP	29 to 31	28 to 32
12.	HS	29 to 32	8 to 12
13.	HT	34 to 37	13 to 17
14.	HU	37 to 40	17 to 21
15.	HW	59 to 62	10 to 14
16.	HX	65 to 68	15 to 19

TABLE 2
Composition Ranges of the Main Wrought High Alloys Used in Heat-Resistant Applications

Type Nos.*	Nickel, Percent	Chromium, Percent
420.....	.....	12-14
431.....	2-5	14-18
442.....	.....	18-23
446.....	.....	23-30
325.....	7-10	19.5-23.5
		Cu 1-1.5
302.....	8-10	17-19
302B.....	8-10	17-19
		Si 2-3
309.....	12-15	22-24
310.....	19-22	24-26
311.....	24-26	18-21
330.....	33-36	14-16
	61	16
Inconel.....	79.5	13

* Type Nos. as given by the American Iron and Steel Institute, 1942.



NOTE: STABLY AUSTENITIC ALLOYS IN REGION TO RIGHT OF D-E-F. MARGINAL AUSTENITIC ALLOYS IN ZONE C-E-D-C. MARTENSITIC AUSTENITIC ALLOYS IN ZONE A-E-C-B-A.

BOUNDARY FOR FULLY AUSTENITIC CONDITION	HEAT TREATMENT
A - E - F	2 HOURS AT 2100°F., WATER QUENCHED
B - E - F	100 HOURS AT 1800°F., AIR COOLED
C - E - F	48 TO 100 HOURS AT 1600°F., AIR COOLED
D - E - F	COLD DEFORMATION + HEATING AT 1200° TO 1600°F. FOR 24 TO 500 HOURS.

Figure 2—Structural diagram for iron-nickel-chromium alloys in various conditions of heat treatment. Alloys also contain about 0.4 percent carbon, 1.2 percent silicon, and 0.8 percent manganese. (Alloy Casting Institute: Reference 20).

useful heat-resistant qualities are found, extend from about 10 percent chromium to 30 percent chromium and from 0.0 percent nickel to as much as 80 percent nickel for plain Cr-Ni alloys within this range of chromium contents.

Figure 1 shows the standard commercial Fe-Ni-Cr alloy compositions, as designated by the Alloy Casting Institute, located on a ternary composition diagram according to their nickel and chromium contents. Table 1 also gives these composition ranges of these alloys and the ACI designations.

The nickel and chromium contents of the principal wrought alloys used in heat applications are given in Table 2.

Properties as Related to Composition

Corrosion resistance, while generally being an important factor governing the choice of a heat-resistant alloy, is but one of many factors which affect the usefulness of the Fe-Ni-Cr alloys in engineering applications. Other important properties are discussed in order that it may be understood why many of the industrially important alloys are more highly alloyed than need be

from the standpoint of corrosion resistance alone.

Those alloys with an austenitic type of structure (face-centered cubic) possess the maximum strength and stability of structure at high temperatures, and they are, therefore, used most extensively in high-temperature applications. Figure 1 shows the range of composition within which this structure occurs at 1800° F. for cast alloys containing in addition to nickel and chromium about 0.4 percent carbon, 1.2 percent silicon, and 0.8 percent manganese. The complexity of structures associated with other ranges of composition are also shown.

Figure 2 shows how the boundary line at the minimum nickel and chromium contents for austenitic alloys is shifted with various temperature conditions. These two diagrams were developed by studies conducted for the Alloy Casting Institute.

The difference in strength properties that exists for alloys containing about 25 percent chromium and 12 percent nickel, which are properly balanced to be wholly austenitic, and for those of composition such that some ferrite and/or the sigma

phase is also present has been demonstrated by Gow and Harder.¹ It was found that the composition boundary line in this chromium range is defined by the following formula:

$$\frac{\text{Cr} - (16 \times \text{C})}{\text{Ni}} = 1.7.$$

This formula is termed the "ratio factor," and alloys with a ratio factor greater than 1.7 are partially ferritic, of lower strength, and structurally less stable than the alloys with a ratio factor of less than 1.7, which are wholly austenitic.

Figure 3 is a plot of creep test data versus ratio factor values, as constructed by Foley² from information contained in a paper by Avery, Cook and Fellows,³ which substantiates the findings of Gow and Harder and demonstrates clearly the superior load-carrying ability of austenitic compositions and the rapid loss of strength when ferrite is

present to only a limited extent in the structure.

The L.C.S. (limiting creep stress) value referred to in Figure 3 is the tensile stress, in pounds per square inch, which gives a creep rate in the second stage of 0.0001 percent per hour (1.0 percent per 10,000 hours). The heats with nitrogen contents above 0.09 percent are so marked, as are those containing a molybdenum addition. The other heats which fall closely on the straight line are of normal composition.

Creep test data, which are considered to be the most usable information in engineering design, are given in Figures 4 and 5 for two of the most prominent alloys used as structural members in high-temperature applications. These are the 25 percent chromium-12 percent nickel (HH type)³ and the 35 percent nickel-15 percent chromium (HT type).⁹

The solidus temperatures (tem-

peratures of incipient fusion) of relatively pure Fe-Ni-Cr alloys, as determined by Jenkins, Bucknall, Austin, and Mellor⁴ are given in Figure 6. Table 3 gives the liquidus and solidus temperatures of two important ranges of cast alloy compositions of industrial importance as reported by Gow, Brasunas and Harder,⁵ from which it will be evident that the minor elements (carbon, silicon, and manganese) lower the melting temperature.

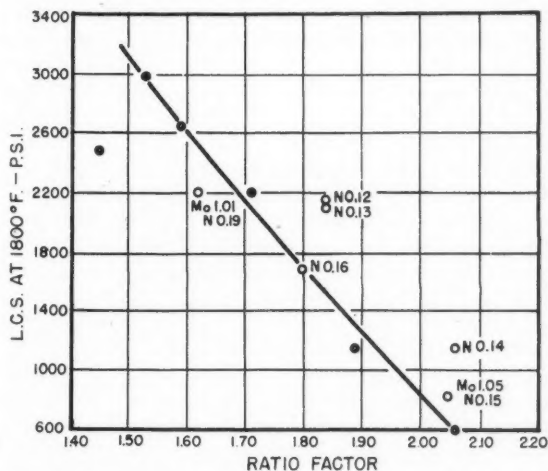


Figure 3—Ratio Factors plotted against "limiting creep stress" at 1800° F. (Alloys of the 25 percent chromium-12 percent nickel type.) (Foley: Reference 2).

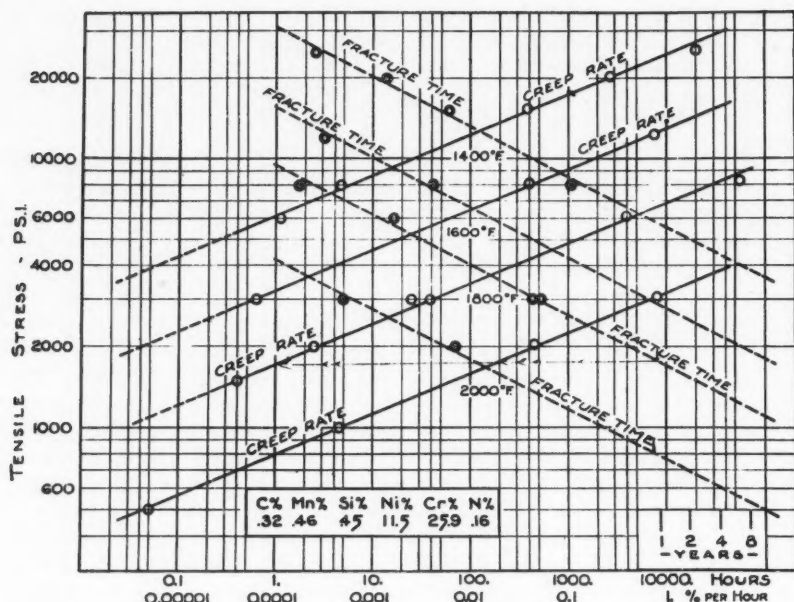


Figure 4—Creep and rupture characteristics from 1400 to 2000° F. for an alloy containing 26 percent chromium and 12 percent nickel. The extrapolated fracture time lines represent the maximum life expectancy. (Avery, Cook and Fellows: Reference 3).

It is to be recognized that stress, and especially alternate stress, is the primary cause for most failures of heat-resistant structural members. The load-carrying ability of the alloys being closely related to their structural features, main consideration must be given to the alloy composition to provide the desired structure. Microstructural features other than that of the matrix structure are also of importance, especially as to the carbide phase, in regard to the amount of it present, its distribution, continuity, and stability. The load-carrying ability being a function of temperature, strict attention must be given to design features, to avoid localized overheating to temperatures not considered in the engineering design.

Corrosion attack in the form of general surface scaling and sub-surface corrosion attack are, of course, contributing causes of failure through acting to reduce the cross section of the member and thereby increasing the unit stress and/or providing points of stress concentration.

Hot-Gas Corrosion

The relative resistance of metals to high-temperature oxidation corrosion is known to be determined by their ability to form a protective scale layer. The degree of protection afforded by the scale is, of course, directly related to the factors affecting its structure. These are: the analysis of the metal, the composition of the ambient atmosphere, and the time and temperature of ex-

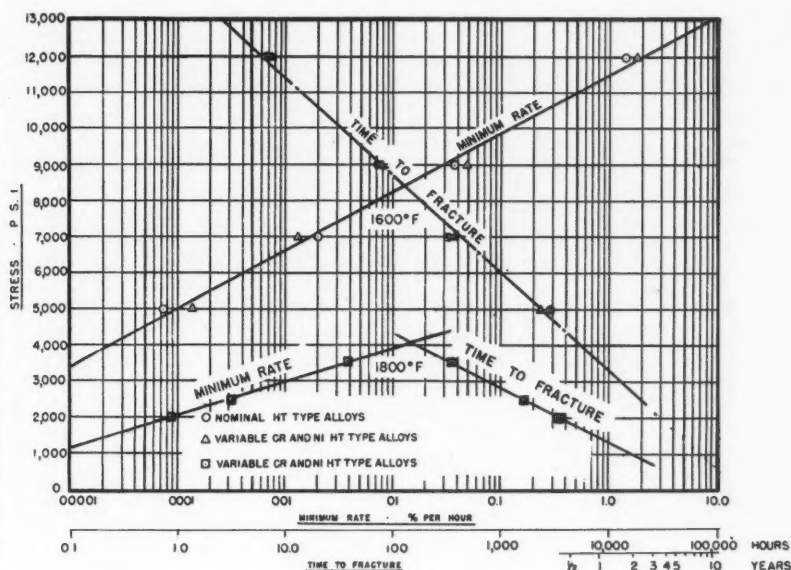


Figure 5—Average minimum rate and fracture time at 1600° F. and 1800° F. for HT type alloys. (Alloy Casting Institute: Reference 9).

posure. In regard to the composition of the metal, it is to be pointed out that the major elements do not always have the controlling influence and that the certain minor elements present may be of prime importance at times.

Gas-atmosphere corrosion is definitely complex, and the fundamentals are inadequately understood at the present time. Broad generalizations regarding the relative corrosion resistance of different alloy compositions based on the experience gained in one type of application or on the results of tests conducted under one set of conditions are, therefore, likely to be entirely wrong in their implications when corrosion conditions other than those for which the observations were made are encountered.

The complicating factors which

may arise to influence the corrosion behavior are: a different composition atmosphere; periodic variations in the composition of the ambient atmosphere; time of exposure; temperature of exposure; thermal shock conditions; mechanical stress and abrasion; contact with materials which may have a fluxing action, and different proportions of the component metals in the alloy.

Forms of corrosion other than surface scaling also must be given consideration, which might be classed as subsurface corrosion, and which at times are more active than surface scaling. Subsurface corrosion may be of one or more types such as: decarburization, carburization, nitridation, interdendritic or intergranular penetration, or selective infiltration attack.

If attention is not given to these

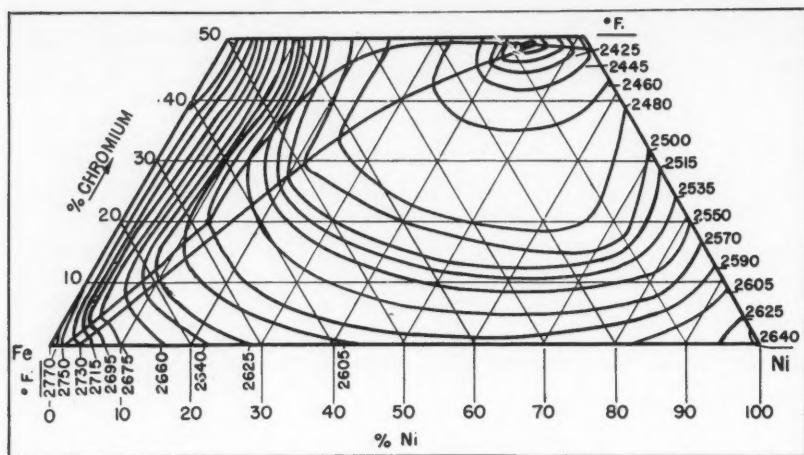


Figure 6—The solidus surface of the Fe-Ni-Cr system. (Jenkins, Bucknell, Austin and Mellor: Reference 4).

possible attendant factors when reviewing the literature, or when noting what is used in service, one will often be left with the thought that the information obtainable is conflicting. Too frequently these factors are not given in reporting researches and case histories.

In order to take advantage of the widely diversified corrosion-resistant properties of this alloy series, careful analysis must be made of the conditions of the intended service, to identify the condition which may be critical. The range of alloys having adequate corrosion resistance is, of course, greatest as the requirements moderate, and becomes narrowed as the requirements become more exacting, or the corrosive conditions more severe.

The main atmospheres to which the alloys are exposed at high temperatures are air and the products of combustion of fuel (flue gas), both of which cause oxidation corrosion or scaling of the alloys. However,

reducing and even carburizing conditions are encountered.

In the case of flue gases, which are the atmospheres most often contacting heat-resistant alloys and which generally contain sulfur, the amount of sulfur and the degree of oxidation of this complex atmosphere have an important influence on the severity of corrosion to be encountered. The terms, *reducing*, *neutral* and *oxidizing*, used in reference to a flue gas refer to the following respective conditions of combustion:

1) *Reducing*. A deficiency of air for complete combustion of the fuel, containing free hydrogen, carbon monoxide, and sulfur gas mainly as hydrogen sulfide or sulfur vapor.

2) *Neutral*. Complete combustion, containing carbon dioxide and the sulfur generally completely converted to sulfur dioxide.

3) *Oxidizing*. Having air in excess of that required for complete combustion and containing uncombined oxygen, carbon dioxide, and sulfur

gas as sulfur dioxide. The sulfur content of a gas is generally referred to in terms of percent by volume of sulfur dioxide (SO_2) or hydrogen sulfide (H_2S), or as grains of sulfur per 100 cubic feet of gas (gS). The following formula converts from one value to the other: one grain of S per 100 cubic feet of gas (1 gS) = 0.00164 percent by volume of SO_2 .

Unpurified fuel gas may contain as high as 600 gS. When combusted, the products of combustion may contain as high as 125 gS. The normally purified coke oven or producer fuel gas contains some 30 gS and the products of combustion about 6 gS.

Bituminous coal contains sulfur in the range of 1.0 to 5 percent by weight. The products of combustion of such fuel would contain sulfur ranging from 55 to 300 grains per 100 cubic feet.

A good grade of fuel oil generally contains about 0.7 percent sulfur by weight; however, the sulfur content of some fuel oils may be as high as 2.5 percent. The products of combustion of an average fuel oil contain about 60 grains of sulfur per 100 cubic feet of gas.

Thus, because of the importance of sulfur, it is basic to know the sulfur content of the atmosphere to which the alloy will be exposed and whether the sulfur will be in the oxidized or reduced form.

Corrosion in Simple Gases

Oxygen, Steam, Carbon Dioxide, and Sulfur Dioxide.

Before considering the relative corrosion resistance of the simple Fe-Ni-Cr alloys, or the more complex alloys with additional elements, to air and flue gases, it is of interest

TABLE 3

Liquidus and Solidus Temperatures of Cast Iron, Nickel, and Chromium

A. Alloys of the 35% to 40% Ni, 15% to 20% Cr Type, with about 0.45% C, 1.2% Si, and 0.80% Mn.

Approximate Nickel, Percent	Approximate Chromium, Percent	
	16	20
35-36.....	L=2500° F. S=2333° F.	L=2490° F. S=2345° F.
39-40.....	L=2480° F. S=2320° F.	L=2475° F. S=2322° F.

B. Alloys of the 25% Cr-12% Ni Type, with about 1.6% Si, 0.85% Mn, and Carbon as Shown.

Approximate Nickel, Percent	Approximate Chromium, Percent	
	23	25
12-13..... (0.35% C.)	L=2555° F. S=2485° F.	
12-13..... (0.53% C.)		L=2520° F. S=2305° F.

Note: "L" refers to the liquidus temperature, which is the temperature at which solidification commences on cooling. "S" refers to the solidus temperature, which is the temperature at which solidification is completed on cooling. (Gow, Brasunas and Harder; Reference 5.)

to become acquainted with the response of the metals, at increasingly high temperatures, to the simple gases present in the air and the complex flue gases. To demonstrate this, Figure 7 was constructed from data reported by Hatfield.⁶ In conducting the tests, the specimens of the metals shown on the figure were exposed for 24 hours to oxygen, steam, carbon dioxide, and sulfur dioxide at temperatures from 700° C. (1292° F.), to 1000° C. (1832° F.).

The following behaviors are to be noted: each of the metals show about the same order of resistance to attack whether the atmosphere is oxygen, steam, or carbon dioxide. In the case of the sulfur dioxide atmosphere, the order of attack on some of the metals is far different than in the other atmospheres. It is shown that cobalt is attacked severely at all temperatures. In the case of nickel, the attack is very

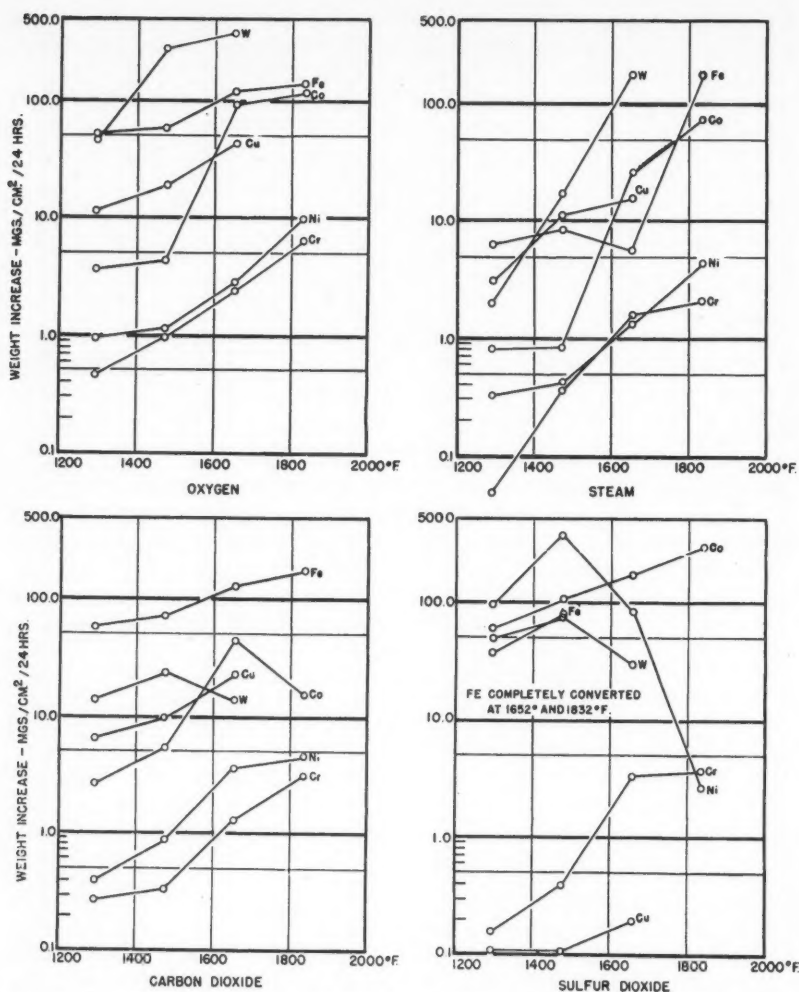


Figure 7—The corrosion attack of simple gases on various metals at increasingly high temperatures. (Constructed from data of Hatfield: Reference 6).

heavy at 1475° F. but decreases at higher temperatures so that at 1830° F. that attack is no greater than that in oxygen.

Tungsten and cobalt are attacked nearly as severely as iron.

The relative order of resistance of the different metals is shown not to be the same at all temperatures. As the temperature is raised, the attack increases in most instances, but there are exceptions shown, the most

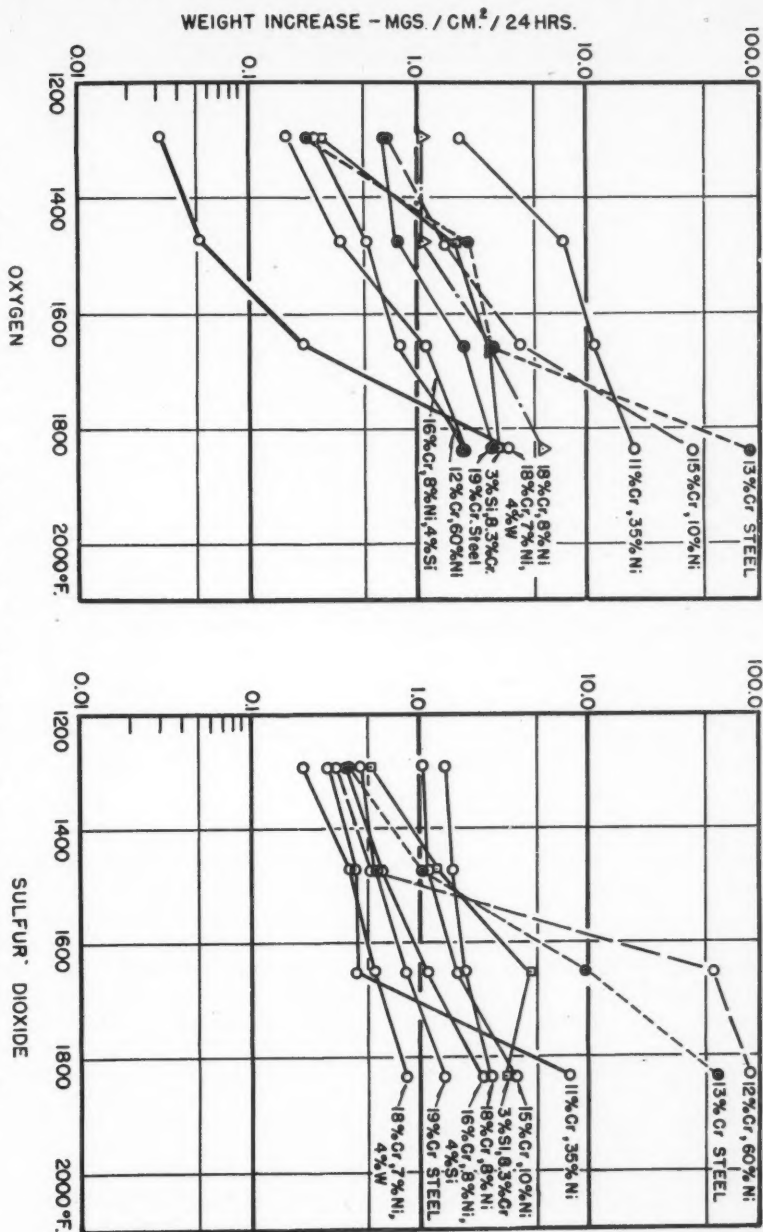


Figure 8—Corrosion attack by oxygen, and sulfur dioxide on alloys. (Constructed from data of Hatfield: Reference 6).

TABLE 4
Effect of Silicon on Pack-Carburizing Behavior of HT Alloys at 1700° F.
 (% $\frac{1}{2}$ -Diam. x 1"-Long Specimens Weighing 14 \pm Grams⁽¹⁾)

Alloy	CHEMICAL ANALYSIS, PERCENT					CONTINUOUS EXPOSURE, 125 HOURS AT 1700° F.			INTERMITTENT EXPOSURE TEN 13½ HOUR PERIODS ²			
						Weight Change, Percent		Carburized Depth, Inch	Weight Change, Percent		Carbon Content, Percent	Carbon Increase, Percent
	C	Mn	Si	Ni	Cr	3	4		3	4		
C-27....	0.46	1.02	0.43	34.9	15.3	+0.68	+0.68	0.099	+0.845	+0.749	1.30	0.84
H.....	0.52	0.74	0.53	34.9	15.2	+0.67	+0.52	0.098	+0.677	+0.544	1.36	0.84
U.....	0.18	0.60	0.53	37.1	17.6	+0.86	+0.39	0.044	.....	.....	.....	.....
ZB.....	0.39	1.06	0.66	34.8	16.7	+0.51	+0.17	0.010	+0.762	+0.652	.....	.....
J.....	0.54	0.74	1.06	34.5	14.9	+0.23	+0.12	0.000-0.04	+0.214	+0.159	.....	.....
L.....	0.53	0.92	1.31	3.44	17.3	+0.23	+0.13	0.000-0.04	.....	.....	.....	.....
O.....	0.46	0.97	1.31	37.1	15.9	.....	.....	.....	+0.114	+0.023	.....	.....
W.....	0.66	0.76	1.34	37.1	15.6	.....	.....	.....	+0.109	-0.034	.....	.....
C-28....	0.43	0.95	1.60	34.9	16.6	+0.07	-0.008	0.000	+0.063	-0.028	0.32	-0.11
K.....	0.84	1.03	1.95	40.8	14.4	.....	.....	.....	+0.073	-0.042	.....	.....
C-29....	0.45	0.91	2.47	35.6	16.0	+0.08	-0.042	0.000	+0.059	-0.041	.....	.....

¹ Packed in E. F. Houghton Company's "Quick Life 'A' Carbonizing Compound".

² Fresh compound used for each exposure period.

³ At end of test, without descaling.

⁴ After descaling electrolytically in fused salt bath.

notable being in the case of nickel in sulfur dioxide. There is not, in all cases, a proportional relationship between the attack and increase in temperature. In certain instances, the attack is shown to become greatly accelerated with increasing temperature.

Nickel and chromium are shown not to differ greatly in the degree of attack in oxygen, steam, and carbon dioxide, while the attack on iron is severe in all conditions.

It is next of interest to note the behavior in simple gases of alloys of iron, nickel, and chromium, in which they are alloyed in different proportions. Figure 8, showing the scaling encountered in oxygen and sulfur dioxide, was constructed from data by Hatfield.⁶

A direct comparison may be made of the attack suffered by the alloys with that which was noted for the individual component metals in Figure 7. It becomes at once evident that one cannot deduce from the corrosion behavior of the constituent

metals what degree of corrosion is to be expected for the alloy. Many of the alloys of iron, nickel, and chromium show superior corrosion resistance as compared to that of chromium, which was the most resistant of the single metals. Some of the alloys which are very rich in iron are shown to be more resistant to corrosion than others containing less iron.

A 4 percent tungsten addition to an 18 percent chromium-7 percent nickel steel markedly improved the corrosion resistance. A silicon addition is shown to enhance the corrosion resistance. A 60 percent nickel-12 percent chromium alloy, while resisting corrosion well in oxygen, is corroded severely in sulfur dioxide. These examples indicate the possibilities and need of correctly proportioning the iron, nickel, and chromium contents and added elements to provide superior alloys.

Nitrogen

The nitrogen in air or flue gases is considered as being essentially non-

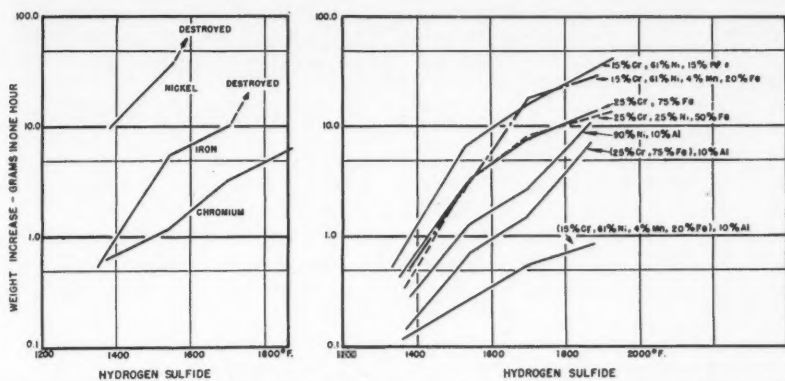


Figure 9—Corrosion attack of hydrogen sulfide gas on metals and alloys. (Gruber: Reference 10).

reactive with the simple Fe-Ni-Cr alloys. It, however, has been reported by Hessenbruck and others⁷ that the aluminum-containing, high-nickel-content Fe-Ni-Cr-Al alloys do react to some extent with the nitrogen in air and especially with a nitrogen atmosphere to form internal complex chromium-aluminum nitride inclusions.

Hoyt and Scheil⁸ have also shown that certain Fe-Cr-Al alloys, when heated in air at high temperatures, are prone to nitrogen being diffused into the interior of the metal, there to be precipitated as a complex nitride. This they had initially termed "internal oxidation," but in recent conversation with Dr. Hoyt he said that later work proved this identity to be in error.

According to Dr. Hoyt, the successful application of Fe-Cr-Al alloys as electrical heating elements is dependent upon a preoxidation treatment which provides an oxide coating high in alumina which is impermeable to nitrogen.

It is known that, under certain special conditions, nitrogen does attack Fe-Ni-Cr alloys, as in appara-

tus for nitrogen fixation or in chambers for conducting surface nitriding of steels with the use of ammonia gas. Nickel-base alloys are generally found most suitable for such applications.

Carbon Monoxide and Hydrocarbon Gases.

Heat-resistant alloys often are used in contact with carburizing compounds and gases which contain sufficient carbon monoxide or hydrocarbons to be carburizing to ordinary steel. The alloys generally considered to satisfactorily resist the absorption of carbon in carburizing environments contain 30 to 70 percent nickel and 12 to 20 percent chromium.

Recent studies conducted for ACI⁹ (Table 4), however, have shown that the silicon content is highly important in inhibiting carbon absorption by a 35 percent nickel-16 percent chromium alloy when contacted by a pack-carburizing compound. The data indicate that, at a low silicon content of about 0.5 percent, appreciable carburization occurs and that a silicon content of about 1.5 percent has effectively inhibited carbon ab-

sorption under these conditions of exposure. The studies are being extended to other carburizing environments and alloy compositions.

Hydrogen Sulfide.

The results of corrosion tests of one-hour duration in hydrogen sulfide for a limited number of alloys, as reported by Gruber,¹⁰ are shown in Figure 9. The severe corrosion encountered in this gas is at once evident. The relative corrosion resistance of chromium, iron, and nickel to this gas decreases in the order named. An alloy of 25 percent chromium, balance iron, shows moderately better corrosion resistance than iron at all temperatures. A 10 percent aluminum addition markedly improves the resistance of nickel to corrosion, while it does not improve the resistance of iron. A complex alloy of 15 percent chromium, 61 percent nickel, 4 percent manganese, 20 per-

cent iron, to which 10 percent aluminum is added, is shown to be the most resistant to corrosion by this gas.

Gruber ascribed the effect of aluminum to increasing the melting temperature of the sulphide formed and to the formation of a dense scale containing alumina.

From these data, demonstrating the corrosion influence of the simple gases, it is made clear that the reducing flue-gas atmospheres containing hydrogen sulfide and reducing gases containing carbon monoxide, hydrocarbons or ammonia are the most dangerous atmospheres with which the heat-resistant alloys will have contact. It will be shown in later discussion that the seriousness of a sulfur-containing, reducing flue gas is dependent on the amount of sulfur present and its state of oxidation or reduction.

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The Determination of Pipe Protection By the Continuous Polarity Method*

By Wm. E. Huddleston*

THIS CONCEPT of determining the state of protection of a pipeline operating under cathodic protection is based on the theory that a metal must be maintained completely negative in polarity with respect to surrounding soil if full protection against external electrolytic corrosion is to be attained.

The method involves measurements that are made to ascertain the pipe surface polarity at all points along the line rather than observations that relate to the difference of potential between protected pipe and soil.

Procedure Used in Determining Spread

After cathodic protection has been installed on a pipeline it is usually desirable to determine the extent of spread that is being afforded. This is done by observing the IR drops at suitable intervals along the pipeline while the cathodic load is held closely to a constant value. So long as a gain in line current flow is observed toward the source of cathodic load, the polarity of the pipe surface is continuous and the pipe is considered adequately protected. This

is illustrated in Figure 1. If, however, such measurements show that the polarity becomes discontinuous with accompanied discharge of protective current from the pipe surface, the pipe at such points is regarded as being in a highly anodic state, and protection is considered inadequate. Such a condition is shown at point A, Figure 2.

Considerable discretion is required during the observation of spread and in the localizing of anodic points on cathodically protected pipelines on which stray currents from electrolysis are superimposed. In most such cases anodic areas will be found, and it is invariably difficult to locate and remove them. Obviously, the presence of rapidly varying line currents necessitates simultaneous readings by at least two observers.

How Anodic Areas Are Located and Removed

Usually, anodic areas are localized fairly close, that is, within approximately 1500 feet, and are located by means of IR drop readings observed along the pipeline. The localized portion of the pipeline is then traversed with an electronic detector, in order to ascertain all coating flaws within the traversed area.

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Having located and staked the voids in the protective coating, the pipeline is then uncovered at such locations and the line current flow is checked to make sure that the anodic areas have been removed.

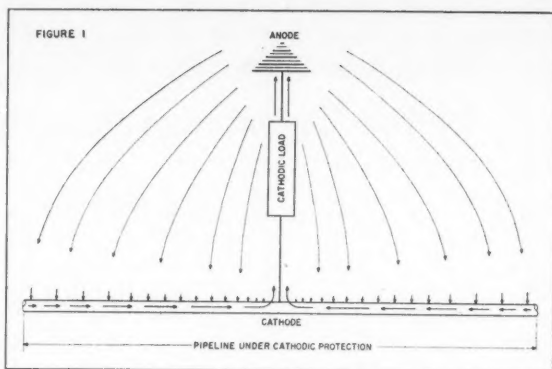
It is then only necessary to make repairs to the coating flaws, backfill the line and recheck the area once more to have complete assurance that the flaws were repaired properly. Usually, coating voids are due to skid marks made during construction of the pipeline, and accordingly, the repairs are a simple procedure and can be performed readily with a nominal amount of materials and personnel.

The following are specific examples of locating and removing anodic areas on pipelines that were operating under cathodic protection:

Case I

A well-coated and wrapped line was placed under cathodic protection, using conventional rectifying equipment. The line was subjected to severe electrolysis at the time the rectifying equipment was installed, and observations made after a protective load of 31.0 amperes at 19.5 volts was applied revealed that electrolysis components were still present.

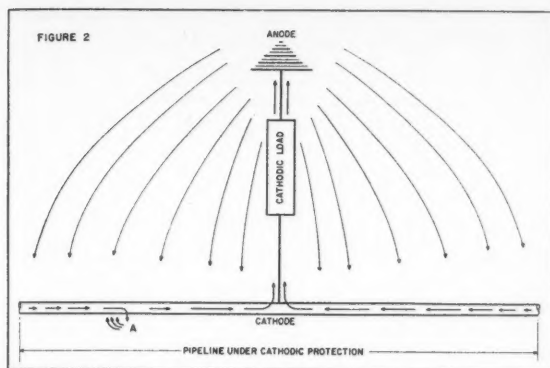
Figure 3 shows a detail of the measurements that were taken at points two miles away from the cathodic load. It was noted that current surges prevailed at the south



end of one mile of line to the extent that the line current drop varied from 16.5 to 16.9 millivolts. A simultaneous drop of 16.0 millivolts was observed at the north end of the mile. The anodic area was localized until the entire anodic portion of the pipeline was confined to a 1200-foot section, as seen in Figure 3.

This section of line was then traversed with an electronic detector, illustrated in Figure 4. Five distinct coating voids were noted. Accordingly, the line was excavated at all five places and the coating repaired, while observers noted the readings of millivoltmeters that were set up on each side of the anodic section.

Upon removing the soil from around the pipe at the five places, it was noted that the reading on the remote millivoltmeter dropped to a constant value of 15.0 millivolts, while the other instrument remained constant at its original value of 16.0 millivolts. This indicated that the pipeline no longer had a discontinuity of polarity, but instead, it actually gained a flow of 1.0 millivolt across the entire mile.



Case II

Another pipeline, similar in construction and operating under similar electrolysis conditions as the line in Case I, was placed under cathodic protection, and spread determinations were made in accordance with the procedure outlined above. Here, too, it became necessary to investigate conditions in the third mile from the rectifier because of prevailing anodic areas. The presence of electrolysis components made it necessary to make simultaneous readings at the ends of the mile, and in fact at all other necessary points within the mile in order to partly localize the points of current loss.

The coating flaws were again located with the electronic detector and were repaired in the usual manner. A final check across the 1200-foot section that had contained the current losses showed that the pipe was restored to a protective state, but on checking the entire mile it was found that the same differential existed.

Again the anodic areas were localized, excavated, repaired and checked. The section that became

anodic upon repair of the first anodic portion of pipe now checked okay, but the readings across the full mile still indicated that anodic points prevailed within the mile. This process was repeated until a total of seven excavations and repairs were made, after which the differential was reduced from an original

amount of 1.0 millivolt to 0.2 millivolt, or a reduction of 80 percent.

Additional tests revealed that the remaining anodic areas were so distributed as to defy further detection, and therefore no more work was performed on this mile of line. It is believed that very little if any damage will result in view of the wide distribution and low magnitude of the remaining anodic points.

Case III

This case pertains to another coated and wrapped pipeline on which cathodic protection was applied, but no electrolysis currents were present due to the remote distance from such troublesome influences. During the course of observing spread, it was found that one mile of line contained one or more anodic areas. Due to the apparent distribution of the multitude of anodic areas, it was found necessary to rely entirely on the electronic detector to locate the coating voids. Accordingly, the mile of pipeline was traversed and a few flaws were located and repaired. A final check revealed that approximately 75 per-

cent of the original current loss had been corrected, but again it was not possible to locate the small amount of remaining losses due to their wide distribution.

Spread observations in all three of the above examples showed that the pipeline became discontinuous in polarity, thereby undergoing a definite loss of current. In two examples, the current discharges were comprised of electrolysis components but in the third example the current discharges were undoubtedly comprised of a component of protective current from the equipment.

In addition to the above cases of inadequate protection of pipe, several similar cases were encountered from time to time in which no external component of stray-current electrolysis was involved. In practically every case it was possible to locate the defective coating flaws, make minor repairs and thereby change the pipe from a state of anodic condition to a cathodic condition.



Figure 4—Operating the electronic detector.

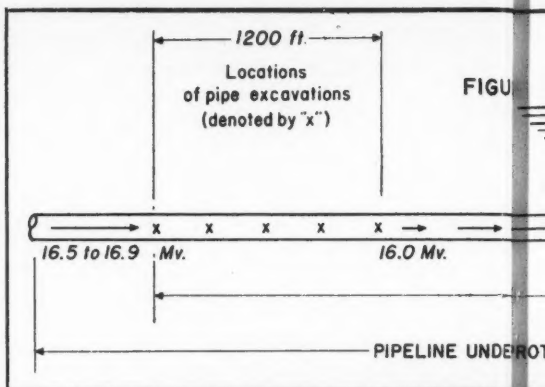
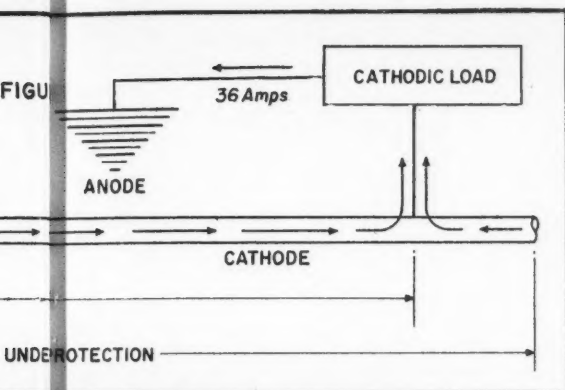


Figure 5—Break in protective coating.

Procedure Used in Making Coating Repairs

All of the coating flaws that were found were mechanical abrasions incurred mostly by skid marks after completion of the coating application. No failures were attributed to the composition of the coating or shielding materials.

Figure 5 shows a typical coating break such as those that are caused by rock depressions. These are repaired by applying a portion of



measurable amount of current within an area usually several hundred feet in extent. (This area may be considerably shorter in the cases of poorly coated or bare lines.) No single point of discharge has ever been encountered—there usually being three or four (sometimes more) points of current discharge within several hundred feet of pipeline.

2) Other than those cases involving components of stray-current electrolysis, the cause of highly anodic points on a pipeline under cathodic protection has not been determined. It has been found definitely that such anodic points are not attributed to protective equip-



Figure 6—First step in repair of coating.

coal tar, cut-back cement, as shown in Figure 6. A piece of wrapping material of suitable size is covered with a layer of the same cold material and is applied in the manner shown in Figure 7. The completed repair is illustrated in Figure 8.

Conclusions

Having recently completed the installation of cathodic protection on 735 miles of pipelines on which spread determinations were made by means of the continuous polarity method, the following conclusions were derived:

1) Although infrequent cases are sometimes found in which a well-coated pipeline under cathodic protection is found to be discharging a



Figure 7—Second step in repair of coating.

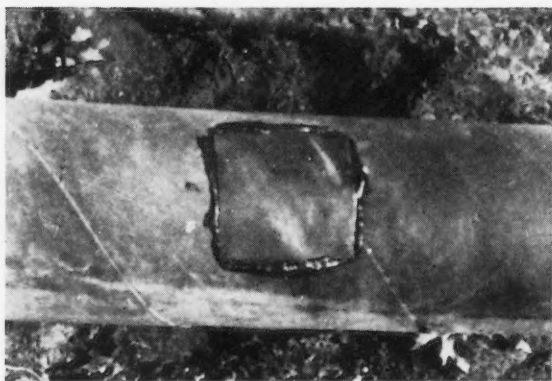


Figure 8—Coating break repaired.

ment or devices or to the composition of the protective coating.

3) Ordinarily an anodic area can be readily found by localizing the current discharges to within a quarter-mile section by means of millivolt drop observations, and then finding the exact points by means of

termining pipe protection is believed to be reliable in that it is based on fundamental theory and it has been used in practice by the writer for a number of years with excellent results. It appears to be valuable in locating and removing sporadic cases of highly anodic points that apparently can not be suppressed by means of cathodic protection.

Discussion

By B. L. Corey*

The paper prepared and presented by Mr. Huddleston should be of primary interest to all corrosion engineers. The matter of current discharge should be investigated more thoroughly, in that it appears to be of a somewhat controversial nature in the case of current losses occurring in relatively close proximity to cathodic protection units, as compared to the generally accepted practice of using pipe-to-soil potential measurements as a criterion of effective protection.

It is suggested that an effort be made to substantiate the data pre-

sented by actual pipe inspections at the anodic points located by the method outlined which have prevailed on protected lines for a sufficient length of time to indicate the seriousness of attack.

It is further suggested that in an effort to throw further light on the effectiveness of this method of locating sections of line in need of coating repair, that surface potential readings as outlined by O. C. Mudd be made to determine what, if any, correlation exists between the indicated current discharge and the observed pipe-to-soil potential readings.

an electronic detector. Use of the latter minimizes the amount of excavation necessary to locate the mechanical abrasions in the coating.

4) Repairs to the few coating flaws that are usually found involves a simple procedure at nominal cost for materials and personnel.

5) The continuous polarity method of de-

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The Corrosion of Iron

By W. R. Whitney*

IT IS MY OBJECT to add to the literature on this subject, the results of some observations of the action of water or steam under various conditions upon ordinary iron, coupled with some consideration of the principles involved.

Owing to the great use made of iron and steel, and the dependence placed upon them, it is not surprising to find that a great deal has been written upon the factors influencing their length of life when used for various purposes.

Practically the only factor which limits the life of the iron is oxidation, under which are included all the chemical processes whereby the iron is corroded, eaten away, or rusted. In undergoing this change, the iron always passes through or into a state of solution, and, as we have no evidence of iron going into aqueous solution except in the form of ions (probably electrically charged atoms), we have really to consider the effects of conditions upon the potential-difference between iron and its surroundings. The whole subject of corrosion of iron is therefore an electrochemical one, and the rate of corrosion is simply a function of electromotive force

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and resistance of circuit. If now we apply Nernst's conception of the source of electromotive force between a metal and a solution, we must conclude from the measured potential-difference that iron in contact with an aqueous solution tends to dissolve, ionize, or oxidize with a force expressed as equivalent to about 10,000 atmospheres' pressure at ordinary temperature.

In other words, iron should tend to dissolve in any aqueous solution until the concentration of the electrically charged iron ions reaches such a concentration that the osmotic pressure is equal to the above value. This means that the saturated iron solution must be at least 450-fold normal, which is a concentration not practically obtainable. Thus far, the theory requires that iron should tend

* Massachusetts Institute of Technology, Cambridge, Mass., now retired.



Figure 8—Coating break repaired.

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In other words, iron should tend to dissolve in any aqueous solution until the concentration of the electrically charged iron ions reaches such a concentration that the osmotic pressure is equal to the above value. This means that the saturated iron solution must be at least 450-fold normal, which is a concentration not practically obtainable. Thus far, the theory requires that iron should tend

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to oxidize in any aqueous solution. Whether it will do so or not depends on other conditions. Something may here be gained by a study of analogies. The dissolving zinc electrode of the Daniell or gravity battery, although possessing an enormous electrolytic solution-pressure, does not dissolve when the electric current is broken, but begins oxidizing immediately when connected through any external resistance to the copper pole. It is not enough then for oxidation or solution of the metal, that it have a *tendency* to dissolve; it must be in metallic connection with some other material capable of acting as an electrode, and this second electrode, if a positive element, must have a lower electrolytic solution pressure than the iron. Iron in contact with zinc and an aqueous solution will therefore not dissolve; but if copper replace the zinc the iron will dissolve, the velocity of solution in these cases being determined by the resistance of the complete electric circuit. These two cases are often met with in practice. In marine boilers, zinc plates are sometimes suspended from the boiler tubes in the water, that they may be attacked instead of the iron. On the other hand, scrap iron is used very commonly to recover copper from solution in mine waters and other copper liquors, in which case the iron rapidly dissolves.

Hydrogen acts as a metal and is electrolytically classified in the group with copper when compared with iron and zinc. That is, if a cell were made upon the Daniell model, iron being used instead of zinc, and hydrogen in place of copper, the cell would generate a current when the iron and hydrogen electrodes were connected. Iron

would then dissolve with a velocity dependent on the total resistance of the circuit. So also, and for the same reason, iron when placed in a solution containing hydrogen ions will dissolve as the hydrogen precipitates, just exactly as when placed in the copper salt solution. That iron does oxidize or dissolve in all solutions containing appreciable quantities of hydrogen ions is well known. This electro-chemical relationship between iron and hydrogen is the primal cause of rusting.

This introduces at once an important point in connection with the subject. Pure water is believed to contain hydrogen ions to the extent of approximately 1 gram for each 10,000,000 liters and should consequently act qualitatively like any other hydrogen-ion solution in oxidizing iron. It is to this extent an acid. It would evidently be quantitatively a very feeble solvent on this basis, if for no other reason than the high electrical resistance of the solution. This is simply another way of saying that in such a dilute solution the hydrogen ions can come into contact with the iron only exceedingly slowly, this contact being necessary for the action. Whether the iron on oxidation or on dissolving remains practically *in situ* as an insoluble compound, oxide, hydroxide, carbonate, basic salt, etc., or is removed as rapidly as it is oxidized, depends on the nature of the surrounding medium. If it be simply in vapor or in moist air, removal of the iron is out of the question. If it be in contact with aqueous solutions, the removal of the iron will be determined by the nature of the negative ions in the solution. If insoluble

compounds can form at the point of corrosion, the iron will not be removed. This is illustrated by the common precipitation of oxide or rusting due to the oxygen dissolved in the water; if no such insoluble compounds are formed, the iron will be eaten away, the surface remaining bright. Both of these processes are very common in practical experience.

There is no doubt that iron, even at ordinary temperatures, reacts with pure water, in accord with this conception. The experiments on this point, carried out by Deville¹ at high temperatures only, showed a balanced condition at various temperatures for the reaction,



He found experimentally that water vapor in contact with iron must produce a certain concentration of hydrogen gas to be in equilibrium; in other words, if the hydrogen was continually removed, the iron could be continually oxidized. Within the range of temperature employed (200 to 1000° C.), he found that the pressure of the hydrogen produced by the action between iron and water increased as the pressure of the water vapor was increased. As the temperature rose, the hydrogen concentration (or pressure) at equilibrium diminished; in other words, the lower the temperature in his experiments, the greater the tendency for oxidation of the iron. According to these results, we should expect water to act on iron to generate hydrogen even at ordinary temperatures, and it is a well-known fact that very finely divided iron such as is obtained by dry reduction of iron salts,

reacts with pure water and generates hydrogen.

This fact, that pure water causes solution of iron, is in accord with other experimentally discovered facts. Mr. G. O. Adams, in connection with a thesis presented to this institute in 1900, made analyses of various samples of gases collected from radiators in different houses where the hot-water gravity heating system is used, and where different water supplies are concerned, and always found a large quantity of hydrogen gas. In most cases, on opening the air-cock of the radiators the gas could be lighted with a match. A number of such mixtures were analyzed. These varied in composition, but were mainly mixtures of nitrogen and hydrogen with usually no oxygen. The hydrogen content varied from 44 to 78 percent by volume. Measurable quantities of carbon dioxide or of hydrocarbons were not usually present.

It is very generally accepted by authorities on the corrosion of iron that the presence of carbonic acid is necessary; but, as water itself must be considered as not greatly different in hydrogen-ion-concentration from a carbonic acid solution in contact with air, it seems *a priori* probable that this accepted idea is incorrect.

Assuming the laws of Henry and Dalton to apply to the solubility of carbonic acid gas in water, also that the solubility of the pure gas under ordinary pressure is one volume for one volume of water (which is correct at 15° C.) and, finally that the normal content of carbonic acid in the atmosphere is 2 parts in 10,000 by volume, we should expect water

in equilibrium with air containing this concentration of carbonic acid to contain 0.0002 volume carbon dioxide per volume of water. This corresponds to a concentration of the carbonic acid equal to 0.00001 mol per liter or 0.00002 normal. From the dissociation constant (3040×10^{-10} determined by Walker,² and to which my attention was called by Professor Noyes, it follows that the first hydrogen of the acid is 16 percent, dissociated at this concentration. From this it follows that 10,000,000 liters of water containing carbonic acid in equilibrium with ordinary air at 15° contains 16 grams of hydrogen ions, or only 16 times as many as perfectly pure water contains. At the boiling temperature the carbon dioxide dissolved would probably yield a concentration of hydrogen ions even less than that in pure water, for not only is the solubility of the gas greatly diminished, but the dissociation of water is greatly increased by rise of temperature. Moreover, the distilling water would rapidly reduce the concentration of any carbonic acid capable of dissolving in water at 100° C.

The following experiment bearing upon this point is one which may have been frequently tried by others, but is worthy of note. To learn whether carbonic acid was necessary to iron-rusting, a clean bottle was steamed out for a time to remove soluble alkali from the glass and was then filled with pure distilled water which was kept boiling by passing steam through it for fifteen minutes. While still boiling, a bright piece of iron was placed in the bottle. A stopper (in some cases rubber and in others cork) carrying a tube

open in a capillary several inches above the stopper, was inserted into the bottle and firmly fastened in place, the water being kept boiling. Finally, the glass capillary was heated hot by means of a blowpipe and sealed by squeezing the walls together. The bottle was then allowed to cool to a temperature of about 80° C., and the neck of the bottle was finally covered with paraffin to prevent leaking. It was thought that in this way the oxygen, carbonic acid and other gases in the water were completely removed. Bottles containing iron and sealed in this manner have stood without any visible change for weeks. In some cases a little air was subsequently admitted to bottles which had stood in this way with the iron apparently unaffected, and within a few minutes the water became cloudy and assumed a yellow color. Ordinary rust rapidly deposited upon the glass and in spots upon the metal. In fifteen or twenty minutes the production of rust throughout the bottle was perfectly evident. It seemed plain from the rapidity of formation of oxide and its precipitation on the glass, that the iron had dissolved in the water before the addition of the air, and that the latter simply permitted the formation of the insoluble oxide.

Mr. J. A. Collins, in connection with his thesis of 1898, performed a similar experiment which shows that the iron is dissolved in the water and that its appearance as rust is a secondary phenomenon due to the action of oxygen on the solution. A cleaned iron pipe 0.5 inch by 15 inches, sealed at one end and having a screw cap to fit the other, was

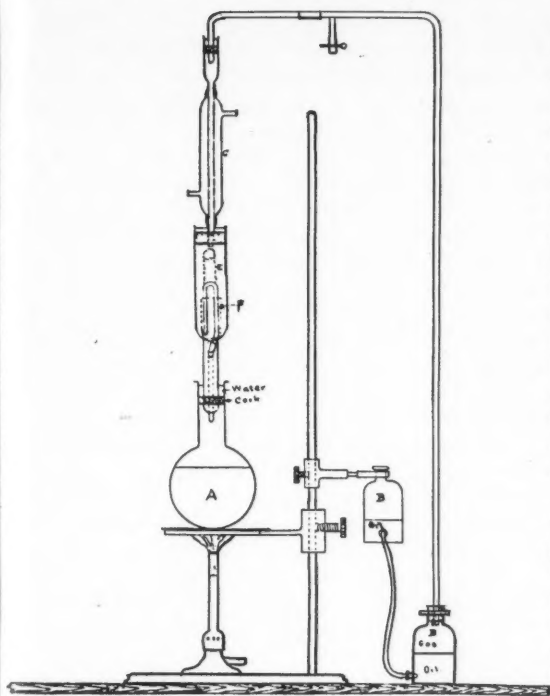


Figure 1

filled with boiling distilled water, and the boiling continued by heating the pipe until half the water had boiled away. While still rapidly distilling, the cap was screwed on tightly and the tube heated to about 125°C . for an hour. On cooling and removing the water from the pipe, it was found to be perfectly clear and colorless, but, on exposure to air in a glass vessel, it rapidly precipitated rust. The pure water had dissolved iron in some form from the clean metallic surface, and this had remained in solution until precipitated by the oxygen of the air. In experiments with air-free water in contact with iron, in glass bottles and flasks, Mr. Collins let into the flasks con-

taining only the pure water together with its vapor and the bright iron, air which had been freed from carbonic acid by being exposed to the action of a barium hydroxide solution in a closed bottle for twelve hours, the bottle being repeatedly shaken to hasten the absorption. In case of this treated air, the production of rust in the flasks was evidently as rapid as with ordinary air.

A similar experiment with purified oxygen gave the same result. One is forced to conclude from such results that if the rusting is due in any way to carbonic acid it is rapidly brought about by such a quantity of this gas

as is left in air or oxygen after treatment with a barium hydroxide solution; in other words, by an inappreciably small quantity. As this acid could owe its activity solely to its hydrogen ions because of the fact that the carbonate ion has no rusting or dissolving action on the iron, it is interesting to note that in the case of recently boiled water, the hydrogen-ion content due to carbonic acid may well be as low as the hydrogen-ion content due to the dissociation of pure water.

Iron dissolves in pure water qualitatively just as in a solution of copper sulphate, hydrogen being deposited in place of copper. The velocity with which this process proceeds

will depend on the temperature and on the hydrogen-ion-concentration in the water. When this concentration is so great that the potential-difference exceeds a certain value, the hydrogen will be evolved as gas, separating from the liquid at the surface of the iron as bubbles. This potential value depends on the state of the surface, so that it is usually higher than the theoretical value for polarization by hydrogen where the gas is in equilibrium with the solution. Below this value, the hydrogen, which is nevertheless being deposited upon the iron, but at a concentration below that corresponding to atmospheric pressure, slowly dissolves in the water, forming an ordinary solution of it, and escapes by diffusion. Its solubility will presumably be proportional to its pressure even though this is below atmospheric pressure.

It was shown by Faraday that an electromotive force below that necessary for visible electrolysis of a solution, was still capable of producing a continuous though feeble current which was then attributed to metallic conduction of the solution. Helmholtz, by his studies of polarization, showed this to be due to actual electrolysis proceeding as above stated. This polarization phenomenon should greatly limit the velocity of solution of the iron, even if no other complicating effect due to the production of an insoluble compound, an oxide or hydroxide, in case air be present. This is usually the case in practice. The production of a compact adherent coating of oxide on the surface of the iron generally retards the corrosive action. Especially is this true at tempera-

tures of steam where the magnetic oxide is formed. This oxide always forms as an adherent solid coating on the iron and seems to be interrupted only by cracks caused by its unequal coefficient of expansion compared with the iron. The red oxide or rust is always flocculent and spongy, besides not protecting the iron, actually seems to increase the velocity of corrosion in its vicinity. It is common to attribute to the red oxide or rust a catalyzing effect on the corrosion of iron.

If the primary rate of corrosion of iron independent of subsequent formation of insoluble substances is simply dependent upon the concentration of the hydrogen ions of the water, anything which reduced this concentration should also reduce the corrosion. The principles of equilibrium of chemical reactions when applied to the dissociation reaction of water should show how, practically, to accomplish this reduction. In this case the product of the concentration of the hydrogen and hydroxyl ions must remain constant in any aqueous solution, for the principle involved declares this product to bear a constant relation to the concentration of undissociated water molecules and this is itself evidently constant in aqueous solutions. From various measurements we are led to believe that the product of the concentrations of the hydrogen and the hydroxyl ions is approximately 10^{-14} . In pure water the concentration of each of the two water ions, hydrogen and hydroxyl, is therefore evidently 10^{-7} . If additional hydroxyl ions are added to the water in any way, the concentration of the hydrogen ions must correspondingly di-

minish, so that the product may remain constant. Thus the corroding power of the water, if due to the hydrogen ions, would be reduced. This reduction of the hydrogen ion concentration may be brought about by the addition of any alkali to the water. That the corrosion is thereby diminished is a well-known fact and one that already receives many practical applications. Iron and steel tools in process of manufacture, between the roughly ground state and the final polished condition, are often kept under water saturated with lime. This prevents the rusting which would quickly take place if they were left in moist air. The effect of the lime must be attributed solely to the hydroxyl ions which in turn reduce the concentration of the hydrogen ions of the water. Neutral salts of calcium do not exert this effect and hence it can not be attributed to the calcium compound nor to the calcium ion. Other soluble alkalies do it equally well and these contain, in common, only the hydroxyl ion.

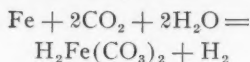
One of the most common components of the many boiler-compounds which are used to prevent pitting and corrosion in boilers, where the water used is very pure and consequently does not form a protecting layer of scale upon the iron, is some form of alkali. The alkalies usually used are caustic, slaked lime, carbonates, borates, aluminates, etc., which are in every case compounds readily undergoing either dissociation or hydrolysis and producing hydroxyl ions thereby. Thus again the concentration of the hydrogen ions is reduced. Conversely, the concentration of hydrogen ions would be increased by the addition of any salt

whose hydrolysis would produce hydrogen ions, and for this reason magnesium chloride, ammonium chloride and similar compounds may increase the corrosive effect of waters containing them.

Free alkali added to a boiler water not only greatly reduces the concentration of the hydrogen ions, from whatever source, thus diminishing the electrochemical reaction of interchange between hydrogen and iron in the boiler itself, but also produces another valuable effect. If a steam or hot-water heating system is fed with a water which is not naturally alkaline, a part at least of the carbon acid, which it always contains, will be driven from the water on boiling and pass to the cooler portion of the system to be redissolved in condensing water. Thus the return pipes of the system will be subjected to the action of this acid or hydrogen-ion solution. No protecting scale of salts from the water being produced in these return pipes, such as is almost always produced in the boiler itself, the corrosive action will be most marked in the return pipes, and especially where the pipes are exposed to the action of continuous supplies of the water in motion. This will prevent the establishment of equilibria and the iron will be continually removed. It ought also to be removed according to the previous discussion, though more slowly, even if no carbonic acid or other acid were present, because of the hydrogen ions of the pure water. This reaction could again be reduced by the presence of volatile alkali in the condensed water, but in practice this latter is usually a negligible effect compared with the effect of volatile acid.

I wish now to show that the effect

of the carbonic acid is actually a cyclic one, the same molecule of acid doing unlimited corrosive work, and that the very harmful corrosion of return pipes in many heating systems may be directly attributed to this usually inconsiderable and unnoticed ingredient of the water. To make this point clear, let us imagine a steam-heating system made up of a boiler, with steam pipes leading to various heating stacks and radiators from which return pipes bring the condensed steam back to the boiler below the water-level. For simplicity, we assume that the plant is run without the addition of water after the boiler has been originally charged. In other words, no steam is blown out into the air and the plant is not used, as some are, to incidentally supply hot water for foreign uses, which thus requires a continual water feed. Our closed system usually contains, when in actual running condition, a number of dead-ends where gases have accumulated and where the pipes are cold. This may be observed in many radiators of common type. Into this colder portion of the system, the gases such as oxygen, nitrogen and carbonic acid, which were originally in the feed water, will collect. Here they will dissolve in the condensed water which is to return to the boiler, the carbonic acid being especially soluble. The carbonic acid or its active hydrogen will cause the solution of iron from the return pipes and this iron will be carried back towards the boiler as bicarbonate of iron, being held in solution just as is calcium carbonate in water containing carbonic acid. This may be represented by the reaction



In the case of the bicarbonate of calcium solution, it is well known that boiling it decomposes the salt and liberates half of the carbonic acid, leaving a precipitate of calcium carbonate. In case of the soluble bicarbonate of iron, as will be shown later, the decomposition of the compound by heat, liberates all of the carbonic acid instead of half of it and produces the insoluble oxide or hydroxide of iron. Whether this decomposition of the soluble iron salt takes place in the boiler after the solution has returned to it, or in the return pipe where the proximity to the boiler produces a sufficiently high temperature, is of no immediate importance. In either case, the carbonic acid is all set free and must immediately return with steam to the cooler parts of the system; there again it will dissolve in the condensate, again render soluble some iron and carry it towards the boiler and so forth. In each cycle of this kind hydrogen will be set free which will remain in the cooler parts of the system, as it is but slightly soluble in water. It seems necessary, therefore, that in common practice a very small quantity of carbonic acid must often cause an unlimited amount of corrosion, without in any way losing its power to continue the process. The process of corrosion of the iron in this case will amount *in toto* to the union of iron with the oxygen of water and liberation of hydrogen, the carbonic acid acting merely as a catalyzer, where the mechanics of its action is apparent. This peculiar condition of affairs has been observed by us in certain large heating

systems where we have found, first the carbonic acid of the feed water; secondly, much carbonic acid mixed with hydrogen, nitrogen, and oxygen in dead-ends or cold parts of the system; thirdly, water in the return pipes, where very rapid corrosion of the piping was taking place in which much dissolved bicarbonate of iron was found; and finally much precipitated oxide of iron in the boiler and hottest parts of the return pipes.

It has been possible also to reproduce these phenomena in the laboratory in various ways and in some cases in glass apparatus where the complete cycle becomes practically visible. In connection with his thesis, Mr. C. L. Wright arranged an apparatus, which is sketch Figure 1. Pure distilled water was boiled in the flask A, and various quantities of air and carbonic acid mixtures were enclosed in the system which was kept nearly at atmospheric pressure by the liquid seal made by the bottles B connected with the condenser C. The steam condensed and took up a little of the carbonic acid; this solution came into contact with a piece of cleaned iron pipe, P, from which the outer layer had been removed in the lathe. This iron was supported in an extractor, E, between the condenser and the boiler in such a way that it was alternately covered with the water and uncovered by the intermittent siphon action of the extractor.

In the first few experiments a precipitate was soon formed in the boiler which was not analyzed, but which was evidently a mixture of hydroxide of iron and silica from the glass. Subsequent experiments in

the same apparatus differed in result from the first one and showed that, in the absence of free oxygen, the boiler water simply became black and opaque but showed little or no precipitate. The glass tube leading from the condenser to the boiler was also quickly coated with a black deposit of iron oxide. It was evident that iron was being dissolved and the resulting compound decomposed in the boiler, and in the hot return tube, but it was at first thought peculiar that the precipitate which appears when the glass or flask is a new one, was not produced in subsequent experiments with the same apparatus. This led to attributing the actual formation of a precipitate in the first case to the presence of dissolved glass. The dark color could only be due to the iron. The clear, black, filterable solution obtained from such previously used apparatus was then shown to be a colloidal solution of iron oxide by the following method: Small quantities of such salts as sodium and barium chloride were added to portions of the clear, black water, and they caused an immediate coagulation and a consequent heavy precipitate, coupled with complete decolorization of the solution. This precipitate, well washed by decantation with pure water, was treated with dilute sulphuric acid in a closed vessel and pure air passed through this and then through a vessel containing a barium hydroxide solution. The failure to produce a precipitate of barium carbonate in this barium hydroxide solution showed that the original compound did not contain a carbonate. The precipitate was shown to contain iron by dissolving

it in acid, oxidizing and precipitating the ferric hydroxide by ammonia. The formation of this colloidal solution of ferrous oxide is in exact accord with the principles which determine the formation of colloidal solutions in general. It is a general principle that whenever any substance which is by nature insoluble, is formed in water, it will tend to remain in a colloidal or suspended state until coagulated by electrolytes.

In the production of most precipitates in common laboratory reactions, there are always sufficient electrolytes present to account for the coagulation of the insoluble substances, if we may judge by the concentration usually necessary where measurements have been made. Where this is not the case, a colloidal state usually results. In the case at hand, there are practically no electrolytes present when the soluble ferrous bicarbonate is decomposed by heat, as this process requires the presence of but exceedingly small quantities of soluble salts in the solution at any one time. The insoluble ferrous oxide consequently remains in the colloidal state. This colloid may be precipitated by salts dissolved from the glass vessel, if of sufficient concentration, as was the case with new glass apparatus, and in this respect this colloid is like many others, such as platinum and silica.

The ease with which the soluble iron salt is decomposed by heat was well shown in the glass tube connecting the condenser and boiler, the return pipe of the above experiment. Above the stopper of the flask, where this tube was fairly cool, the glass remained clear, but below the stopper where the tube was heated by the steam of the flask, it was covered deeply with a black deposit, probably ferrous oxide. The deposition of this substance at this part of the return tube, commenced almost immediately on starting the experiment.

An experiment carried out in this way where pure water and carbon dioxide were used, where analysis showed the gaseous mixture to contain 11 percent carbon dioxide, produced such rapid corrosion of the iron that within a few days nearly a third of the exposed surface had been eaten away to depths of several hundredths of an inch, at which rate an ordinary pipe would not last more than a few months. It is not surprising that carbonic acid should dissolve iron under these conditions, but the fact that this corrosive action is a cyclic one, in which under suitable circumstances even a trace of carbonic acid may dissolve an unlimited quantity of iron without losing its corrosive power, has not received sufficient attention.

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The Electrical Engineer's Responsibility for Recognizing Corrosion as a Factor in the Design of Electrical Structures*

By M. C. Miller*

ALTHOUGH ELECTRICAL engineers have an enviable reputation of being progressive in new developments and modernization, the electrical industry, as a whole, is lagging in application of methods to reduce galvanic corrosion of conduits, lead cable sheaths, and other buried metallic structures.

It would seem that the electrical industry would be out in front in corrosion mitigation through use of electricity to stop corrosion, and in the design of equipment and structures for a minimum of corrosion. This is even more startling when considering that most, if not all corrosion, whether from electrolysis or galvanic corrosion in soils, also atmospheric corrosion, is an electrical phenomenon and should be right up the "electrical engineer's alley." He presumably learned all about it in college.

It has been my observation that many pipeline companies are far ahead of the electrical industry in corrosion mitigation work. However, neither has gone "all out" in a real fight to stop the enormous wastes of materials and money which result from corrosion. The electrical industry, with the electrical engineer's "electrical know-how" could easily lead in this field of corrosion work.

Consider some of the everyday practices used generally throughout the electrical industry in and around generating stations, substations, overhead and underground transmission and distribution systems—practices which cause rather than reduce corrosion.

Copperweld ground rods came into favor 15 to 20 years ago and are now used extensively because of short life experienced from galvanized ground rods. Did galvanized ground rods start to corrode practically "overnight" and thereafter have a short life? Perhaps the life was long in the good old days when the arresters were connected to a separate ground rod and the secondary grounds were not interconnected with water

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systems. With the advent of the common neutral system and interconnection of lightning-arrester grounds and secondary grounds with water systems, the galvanized ground rods became galvanized anodes trying to cathodically protect the water systems and gas systems. Where soil conditions were right, corrosion of the galvanized rods should be rapid—and was. So the use of copperweld rods spread rapidly.

Reason for Many Failures of Lead-Covered Cables

It seems safe to say that many thousands of failures of lead-covered cables are the result of corrosion caused by the extensive use of copperweld ground rods and copper grounding cables at generating stations and substations; also from the use of bare copper neutral cables in duct lines. With lead sheaths solidly interconnected to bare copper and low soil or duct resistances, corrosion of the lead will take place with resulting failures. It is general practice to install copper ground rods in manholes, which adds to the corrosion.

The need for adequate grounding of electric systems to reduce electrical hazards and improve system operations has resulted in widespread use of solidly grounding electric systems to water systems which are connected to gas systems and other buried metallic structures. Fortunately, lead sheath is close in potential to steel and cast iron pipes—but under some soil and duct conditions may be quite anodic to them. This condition will become much more serious when brass and copper pipes are again used extensively for gas and

water services. In some cities copper and brass service pipe were used extensively before the war.

Station and system groundings are intimately associated with corrosion. Where soil resistivity is low (1000-ohm centimeters or less), there is no difficulty in obtaining a low resistance ground—but corrosion of buried conduits, water and fuel piping, stationary and traveling screens, and lead cable sheaths may become a serious problem. Conversely, where soil resistivity is high (30,000 to 100,000 ohm centimeters and higher), it becomes a real problem to obtain a station ground of one ohm or less—but soil corrosion would be a minor problem. In the past and even at present when corrosion due to use of dissimilar metals and corrosion mitigation is fairly well understood, most electrical, mechanical and structural engineers overlook, or ignore these fundamentals in station and system design. Drastic action is necessary to change these design practices which have been accepted as standard for many years.

Simple-Cell Action of Dissimilar Metals Often Overlooked in Designing

Equipment manufacturers must be given their share of criticism. Their design engineers apparently overlook the simple-cell action of dissimilar metals in soils and aqueous solutions. They appear to consider the corrosion and mechanical aspects of each metal separately—rather than all parts as a unit. Sometimes it is a question whether they are designing a mechanical piece of equipment or a multiple corrosion cell. Expensive

maintenance of parts results because of rapid corrosion.

Corrosion from electrolysis (or stray man-made current—such as d-c railway current) can cause extensive failures of pipeline and lead cable sheaths in two or three years, or in a few months in extreme cases, although electrolysis control methods are well known, and practiced on many systems—numerous cases have been investigated where the design engineers have utterly disregarded this most potent enemy, even in some cases where they were specifically warned of serious stray current conditions at the location.

On Use of Copper Ground Rods

Where lead-covered cables are subject to electrolysis from stray street-railway current, the use of copper or copperweld ground rods is especially detrimental and increases the amount of current picked up in the negative areas to be discharged in the positive areas.

In the negative areas, the copper rods being more positive in galvanic potential tend to "electrically pump" current from the ground to the cable sheaths. During light or no load on railway systems, the polarization built up discharges to the copper rods and, it is believed, tends to cause corrosion of the lead in the high negative areas.

In the positive areas also the copper rods are detrimental. As the lead sheath has a higher negative galvanic potential than the copper, the stray current flow to earth would tend to be from the lead, in preference to the copper—unless, of course, a properly adjusted drainage system were provided.

Zinc or magnesium anodes in place of copper rods, from the current pick-up and discharge point of view, would be desirable. They would tend to keep the cable sheaths negative during light load periods. There are some limitations to extensive use of galvanic anodes (especially magnesium) for electric system grounds.

Facts More Convincing Than Theory

Facts are more convincing than theory. After investigating causes of corrosion failures on distribution cables; also corrosion in and around stations, changes in design were suggested to design engineers. It was necessary to collect and present specific evidence backed up by test data and corrosion skeletons to convince those engineers that their design practices (generally similar to those used throughout the industry for many, many years) should be changed to "design against corrosion."

It became apparent that most design engineers, with whom this was discussed, were not fully advised of corrosion experienced in equipment and plant.

A few of the many corrosion investigations made are discussed briefly below as typical examples.

Electrolysis Failures on Lead Cables

Corrosion failures on a high-voltage, oil-filled, lead-covered cable in just a few months in Venezuela is an outstanding example. Design engineers were warned of electrolytic corrosion failures experienced on telephone cables along the same route. The electric cables extended from one edge to the other edge of

the city, and past the one street-railway station. No drainage was provided, although the cables paralleled and criss-crossed the street-railway tracks, which were in a very bad state of repair. Oil leaks developed practically before the cable was placed in operation.

A joint investigation by telephone and electric system engineers showed it to be relatively simple and inexpensive to install electrical drainage and by utilizing the street-railway current, to provide cathodic protection to practically all of the underground cable system in the city. Rectifiers were recommended in outlying areas to supplement the street-railway current.

Bare Copper Neutrals in Duct Line

Cable failures in Miami and Miami Beach, Fla., have been serious in the past few years. Apparently, the street-railway current provided some cathodic protection until the street cars were replaced with buses. It took a few years for galvanic corrosion to cause failures.

In one electric cable duct line, corrosion failures became too frequent. An investigation disclosed that the cables were being corroded because the sheaths were interconnected (as is the usual practice) with an extensive station ground (reported to be large copper plates buried in charcoal) and bare copper cables; also there was a 750-Mcm bare copper cable throughout the duct line. The duct line, about 3000 ft. long, was flooded with salt water. All cables and the bare neutral crossed under the Miami River.

One short section of the 750-Mcm bare neutral was insulated off, and

tests showed it was collecting approximately 0.15 ampere, which would take 12 pounds of lead per year off the lead sheath.

The remedy was fairly simple, and again, relatively inexpensive. The bare neutral was replaced with an insulated neutral. Insulating joints were cut in the sheath of each cable in the cable vault of the station. All cable sheaths were cut clear of neutral in the station, in each manhole, and on each terminal pole. All sheaths were bonded together in each manhole. The resistance to station ground was low enough (approximately 0.006 ohm) to clear any cable fault.

To provide cathodic protection, eight 4-inch by 5-foot magnesium anodes were installed in the river, and 24 in the manholes. These 32 anodes provided 30 amperes of current. These have been in service for about 18 months without a corrosion failure in that duct run since the installation was completed—although there probably were many corrosion pits nearly through the lead. We believe corrosion has been halted. It is being closely watched.

Submarine Cables

Submarine electric cables are a good example of what can be done in the way of incorrect design—insofar as corrosion is concerned. There are a number of submarine-cable crossings between West Palm Beach and Palm Beach. Some of these have been investigated for corrosion.

One 4-kv lead-covered cable with galvanized steel armor was installed about three years ago to replace one which failed. A bare No. 2 copper neutral was laid with it.

As we found it at the start of cor-

rosion tests, the lead sheath was connected to the bare copper neutral at both ends. The neutral, of course, was connected to overhead neutrals, which are interconnected with the water and gas system. The galvanized armor was not connected to sheath or armor at either end. It measured 0.7 volt negative to the sheath, which was good. A short-circuit test showed that, if it had been tied in at each end (as usually is done on these submarine cables) it would have generated eight amperes, with a resulting loss of 200 pounds of zinc galvanizing per year.

After isolating the lead sheath, it was found that it had been generating four amperes of galvanic current—trying to protect the bare copper neutral and water and gas systems. Four amperes means a loss of 300 pounds of lead each year. How long would it be before that cable would fail from corrosion?

The resistance to earth of the lead and armor tied together was low. The remedy was to leave them tied together but isolated from neutral. Cathodic protection was provided with six 4-inch by 5-foot magnesium anodes installed in the manholes at each end of the crossing, a cheap method of providing full protection. The cable-to-earth potential was made negative enough to protect both the lead and the galvanized armor.

Buried Galvanized Conduits in Stations

Galvanized conduits for control cables at a high-voltage substation in New Orleans were badly corroded in less than one year. The substation was built on highly-corrosive, low-

resistance filled-in ground. The soil was filled-in from dredging Lake Pontchartrain, which contains water with a high salt content.

The usual copperweld ground rods and bare copper connecting cables were used. The galvanized conduits were buried in earth and (in accordance with established practice throughout the electrical industry), the conduit and ground bus were solidly interconnected. Naturally, corrosion of the conduits resulted.

The remedy was not simple. Uncovering the conduits and grouting them in with concrete probably was the lowest cost remedy. It should have been done initially, or fibre conduits could have been used.

At that station, the lead sheaths of 13-kv feeder cables are isolated from the ground bus, and separately grounded to heavily galvanized ground rods which also provided cathodic protection.

Corrosion in and Around Steam Stations

In and around steam stations is a fertile field for an ambitious corrosion engineer. Traveling screens, with bronze-screens, steel frames and often galvanized trash lips on each basket, with the structure connected to the copper station ground is a source of constant and expensive maintenance, especially where circulating water is low-resistant and corrosive. In some new stations now under construction, completely galvanized screens and frames—isolated from station ground and reinforcing rods in supporting concrete structure, are being installed. Cathodic

protection will be supplied by magnesium anodes in the intake waters.

Stationary screens also are a corrosion problem. Condenser water boxes and tubes present a corrosion problem—where improvement in design to eliminate dissimilar metals or insulate one from the other or provide cathodic protection, show a possibility of real saving. In one station red brass pipe was used for service water, which was sea water.

Cast-iron valves were used. The body corroded through in about two years. They could have been insulated at practically no cost at the time of installation. The corrosion problems around a steam plant are too numerous to list here.

We are preparing a corrosion experience record for any steam plant where we have an opportunity to do so—to build up a backlog of experience as a guide in future design.

Conclusion

In some forceful manner, electrical engineers should be made corrosion conscious so that they can design *against corrosion*—not *for corrosion*. It would seem that any fairly large electric utility could well afford to have a high-class corrosion engineer (or a corrosion and electrolysis department) who should be consulted on all design practices, to guard against designs which cause corrosion!

The author is of the opinion that engineers in the electrical industry

could accomplish much in the way of reducing corrosion of underground metallic structures by becoming corrosion conscious—and designing such structures in a way which would tend to reduce corrosion. This paper pointed out some of the causes of corrosion inherent in general design practices. There is a need for reviewing these to see if changes could be made which would reduce corrosion while still meeting mechanical, structural and electrical requirements.

Further Discussion of Paper Chemical Corrosion Resistance of Lead*

By Robert L. Ziegfeld*

WHILE WE MUST agree with Dr. Uhlig's statement¹ that general caution is required in employing lead and lead alloy equipment in the food and beverage industries, we must take exception to some of his other discussion of "Chemical Corrosion Resistance of Lead." The list was intended as an engineering corrosion guide only and did not attempt to introduce economic, hygienic and other factors which might be considered but which would make the paper too voluminous.

The Lead Industries Association has spent thousands of dollars over the past 18 years on research at the Harvard Medical School and elsewhere in an attempt to reach a better understanding of lead hygiene, and with marked success. We believe that no industrial hazard is now more widely recognized nor more thoroughly understood. In fact, in 1946, the Lead Industries Association sponsored jointly with the American Medical Association a full

day symposium on this subject. Leading medical men and men from industry were the speakers, and many fallacies about the lead hazard were exposed. These papers will soon be published in the Journal of Occupational Medicine of the American Medical Association.

Furthermore, in 1943, the American Public Health Association published a report, "Occupational Lead Exposure and Lead Poisoning," prepared by a committee of most distinguished medical talent. It is available for those who wish the most up-to-date information on the subject and dispels many earlier erroneous notions.

Dr. Uhlig warns against the cumulative effect of small amounts of lead absorbed by the system, but he does not make it clear that normal amounts of lead so absorbed are eliminated in the urine and feces. For example, the Public Health Association report says, "Nevertheless, practical experience and systematic investigations have demonstrated that certain levels of *occupational* lead exposure and absorption are compatible with normal healthy existence and activity. . . ." The italics are ours. This statement refers to occupational exposure which is far

*Original paper prepared by Lead Industries Association, New York, N. Y. Corrosion 2, 330-333, (1946) Dec.

*Assistant Secretary Lead Industries Association, New York, N. Y.

¹H. H. Uhlig, Discussion of paper on Chemical Corrosion Resistance of Lead, Corrosion 3, 149-150 (1947) Mar.

more severe than the type of exposure to which Dr. Uhlig refers.

Also Drs. Fairhall and Neal of the U. S. Public Health Service have shown in a Public Health Report in 1938 that lead arsenate, which is far more toxic than metallic lead, can be ingested in amounts as large as 10 milligrams per day for 10 days and that 85 percent of it is eliminated from the human system within a few days.

Dr. Uhlig suggests the inadvisability of using lead to convey drinking water under any circumstances. This whole subject was discussed in detail before the New England Water Works Association in 1939 in my paper entitled, "Conditions Covering the Installation of Lead Service Pipe," (Journal of the New England Water Works Association, Vol. LIV, No. 1). This paper, quoting the work of recognized medical authorities, showed that outside the soft water area of

New England, lead poisoning from public water supplies conducted through lead pipe is virtually nonexistent, and that even with the soft New England waters, it was found in only four of more than 300 municipalities surveyed by the Massachusetts State Board of Health. Even in those instances, Weston and others have shown that proper treatment of the water prevents solution of lead or other metals. Many cities like Chicago, New Orleans, Denver and New York supply millions of people every day with water through lead pipes without ill effect. The U. S. Public Health Service has established a safe limit of lead content of drinking water at 0.1 part per million, recognizing that these small amounts are harmless and are eliminated. Very few public water supplies, even untreated, will take up even that small amount of lead.

ERRATA

In the article, "Attenuation of Drainage Effects on a Long Uniform Structure With Distributed Drainage," Corrosion **3**, 6, 301-309 (1947), June, the factor in the denominator of Formulas 5, 7, 12, 13, and 14 should be: $e^{\alpha s} - 1$ instead of $e^{\alpha s} - 1$ as printed.

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A Magnesium Anode Installation For Preventing the Corrosion Of Lead Cable Sheath*

By H. A. Robinson* and R. L. Featherly**

THE CORROSION resistance of metallic lead has long been recognized, consequently, its use by industry in the form of protective linings and sheathing on more vulnerable materials has been and continues to be extensive. Because of its excellent resistance to corrosion by acid fumes and liquors, lead enjoys widespread application in the chemical industry for the construction or protection of chemical processing equipment. For similar reasons, lead is used throughout the electrical industry as a protective sheathing on underground cables used for communication and power transmission purposes.

Corrosion Characteristics of Lead

As is the case with most metals, the corrosion resistance of lead is a relative property determined largely by the nature of the corroding environment, and by the chemical and electrochemical properties of the

metal. So far as corrosion characteristics are concerned, the properties of lead which merit attention are:

- 1) A position just above hydrogen in the electromotive series.
- 2) A relatively high hydrogen overvoltage. A comparison of the cathodic polarization characteristics of lead and steel is given in Figure 1.
- 3) A large electrochemical equivalent (approximately 3.7 x that of steel, weight basis, or 2.5 x, volume basis).
- 4) A tendency to form insoluble salts with most of the common anions, e.g., chloride, sulfate, carbonate, and hydroxyl ions.
- 5) A tendency to be amphoteric, i.e., the oxides and hydroxides of lead tend to dissolve in both strongly acid and strongly alkaline solutions.
- 6) Protective oxide or hydroxide films are formed rapidly in water or moist air, i.e., freshly cleaned lead surfaces tarnish quickly.

The position of lead in the electromotive series suggests a relatively inert metal, but this interpretation is misleading in that the data of the

* A paper presented at the Annual Meeting of NACE in Chicago, Ill., April 7-10, 1947.

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series applies only to an electrolyte rich in lead ions. In practice, lead is often found to be nearly as anodic as clean iron or steel and even may be strongly anodic to well rusted steel. In certain electrolytes, e.g., dilute hydrochloric acid, its use as a sacrificial anode for the cathodic protection of steel has been patented (U.S. Patent 2,149,617).

Causes and Control of Underground Corrosion

The resistance of lead to corrosion by the acid liquors commonly encountered in chemical process work can probably be attributed to its high hydrogen overvoltage, the protective action of insoluble lead sulfate films and, in some instances, to a low concentration of dissolved oxygen in the corroding medium. In underground service, however, the lead sheathing of telephone, telegraph, and power transmission cables is subjected to a much greater diversity of corrosive influences ranging from the electrolytic corrosion associated with galvanic and stray currents to the direct chemical attack produced by the alkalinity of green concrete or the organic acids formed by decaying vegetation.

Because of its large electrochemical equivalent, lead is especially vulnerable to electrolytic corrosion. This, coupled with the pitting nature of the electrolytic attack, makes for a rapid rate of penetration. Likewise, the widespread distribution of dissolved oxygen in soil and soil waters makes for good cathodic depolarization, thereby eliminating the advantage of high overvoltage. A more comprehensive treatment of the causes of cable sheath corrosion, together with suitable methods of

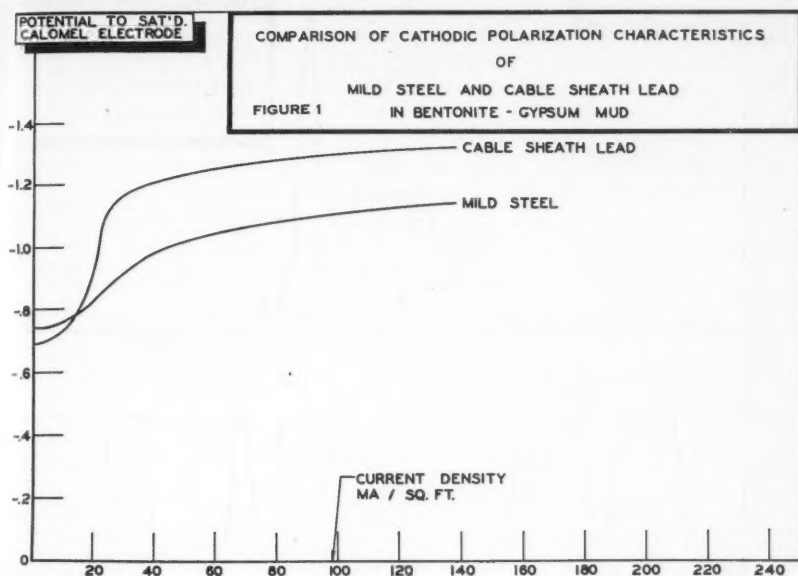
mitigation, has been presented by Gorman.¹

The sheath failures and attendant impairment or interruption of service resulting from such corrosion obviously constitute a costly and troublesome maintenance problem to every operator of underground cable services and, as might be expected from the diversity of corrosion causes, no one corrosion mitigation method is universally applicable. Since a general discussion of these methods may be found elsewhere¹ only the electrical control methods known as (a) bonding or electrolysis drainage, and (b) cathodic protection or forced drainage will be given brief consideration here.

Wherever possible corrosion due to stray current is controlled by suitably bonding the cable sheath to the negative side of the system originating the stray current. This method aims at providing a suitable metallic return path for the stray current thereby eliminating the original electrolytic return causing the corrosion.

Cathodic Protection

The method known as cathodic protection or forced drainage makes use of the electrolytic return circuit but aims at harmlessly diverting the offending current to ground by causing it to discharge through an expendable anode. The application of cathodic protection shifts the cable-to-earth potential toward more negative values and tends to transfer any electrolytic corrosion of the cable sheath to the sacrificial anode. In practice, the distinction drawn between the above methods is somewhat artificial in that both methods apply cathodic protection to the ex-

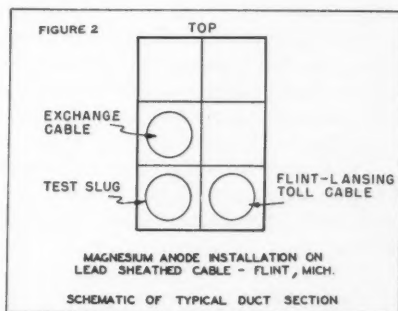


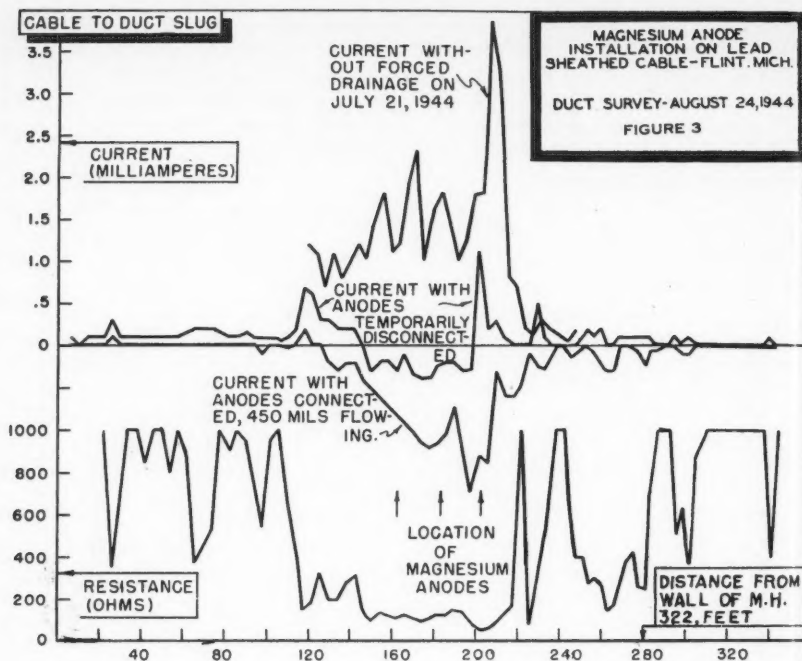
tent of the current drained from the cable sheath.

The theoretical foundations of the cathodic protection method are well known and have been given in more detail elsewhere.^{2,3} Reasonable care must be exercised in its application to lead cable sheath inasmuch as lead is an amphoteric metal. The inadvertent application of excessively high current densities may produce a sufficiently high concentration of alkali at the cable sheath to cause the direct chemical attack known as electrolytic corrosion. Aside from this, the evidence points to its being as effective a corrosion-control method for lead as for other metals.

The application of cathodic protection to cable sheathing may be effected with either a ground bed of scrap metal or carbon anodes buried in the earth near the cable duct, or by coupling the cable sheath to gal-

vanic anodes similarly buried. In the former case, an external d-c voltage must be applied between the ground bed and cable sheath in order to realize current flow in the proper direction to effect protection. The galvanic anode, which consists of a metal well above lead in the electromotive series, automatically sets up a protective current flow, thereby freeing the method from any depen-





dence upon an external source of power.

Heretofore zinc has been the only metal generally available in a form suitable for galvanic anode use, but in 1945 The Dow Chemical Company, after an extensive research program, introduced a magnesium alloy specifically designed for use as a galvanic anode. At the present stage of development these anodes offer several important advantages for cathodic protection applications in general. These are:

- 1) A high potential or driving voltage which makes for a lower installation cost per unit of current delivered,

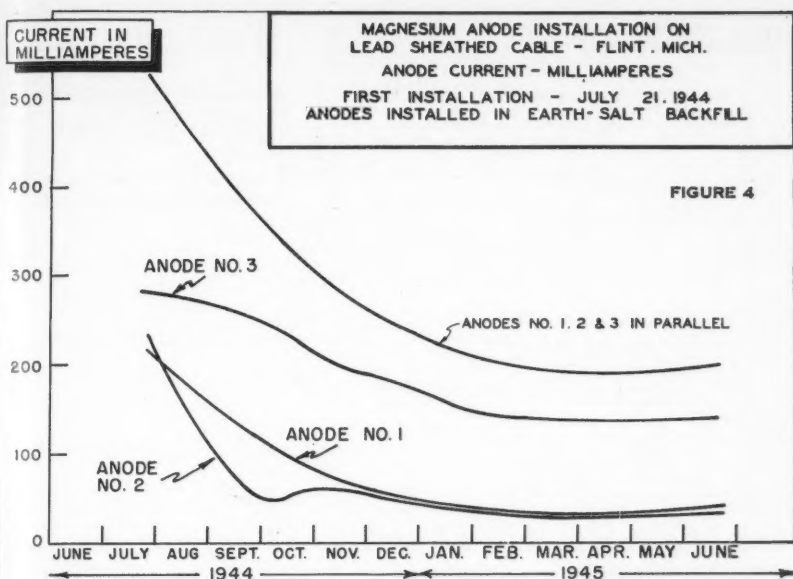
- 2) An electrochemical equivalent of about 500 ampere-hours per pound

of metal consumed under average field conditions, and

- 3) Little or no tendency to polarize when installed in the recommended chemical backfills.

Magnesium Anodes For Cable Sheath Protection

The first experimental use of magnesium anodes for the protection of lead cable sheath was initiated by R. L. Rayner, of the Michigan Bell Telephone Company, Detroit. A test installation site, involving a section of six-compartment duct carrying two lead sheathed cables (see Figure 2), was selected on the west side of Flint, Michigan. Two successive magnesium anode installations were

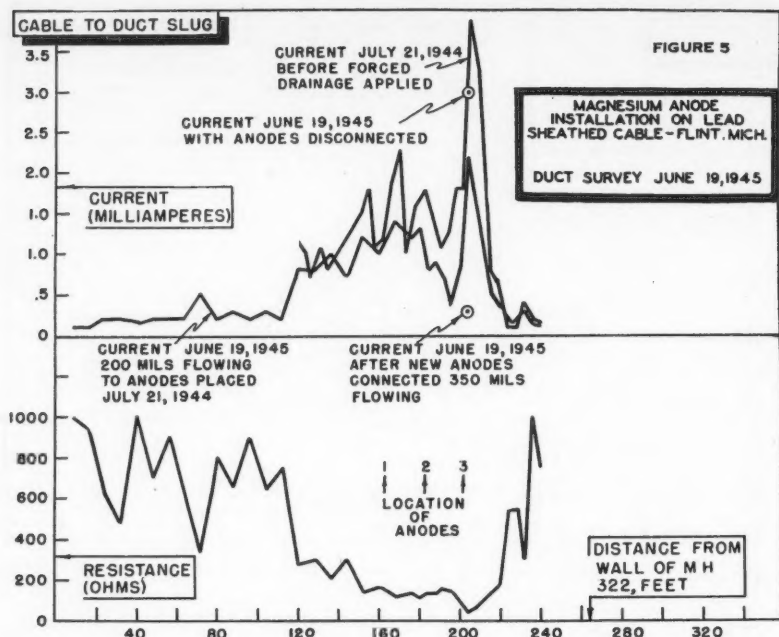


made here, the first of which was installed July 26, 1944.

Selection of the above test site was based on duct survey data obtained by pushing a one-foot slug of test cable into one of the spare ducts and measuring the resistance, voltage, and current flow developed between the cable sheath and duct slug. These measurements (see Figure 3) revealed the existence of some 100 feet of duct run, over which cable-to-slug resistance was particularly low (25-300 ohms), with cable-to-slug currents ranging from 0.75 to as much as 3.9 milliamperes. Positive cable-to-slug potentials of the order of 0.2 volts were also observed. Inasmuch as current flows in excess of 0.5 milliamperes are regarded with suspicion and flows in excess of 2.0 milliamperes usually indicate serious corrosion, the site in question was considered to need

protection. This judgment was reinforced by the presence of a cinder-filled driveway crossing the duct, together with a paralleling cinder-covered yard. The soil resistivity in this area ranged from 2100 ohms per cubic centimeter near one end of the affected section to about 1670 ohms per cubic centimeter near the center.

Preliminary work had demonstrated that a current of 500 milliamperes applied from an anode some seven to ten feet from the cable would be adequate to protect the cable section. Tests were also made to determine the effectiveness of a magnesium anode located in one of the adjacent manholes. In this case, however, the anode-to-ground resistance was too high (28 ohms) to allow a current flow of practical value. Chemical conditioning of the manhole water to reduce anode-to-ground resistance was considered



to be inadvisable for several reasons:

1) Danger of either direct chemical attack on outlying cable due to diffusion of the chemical, or cathodic corrosion resulting from overconditioning and an excessive flow of current to cable within the manhole.

2) Good distribution of the protective current would probably not be obtained even if sufficient current flow was realized.

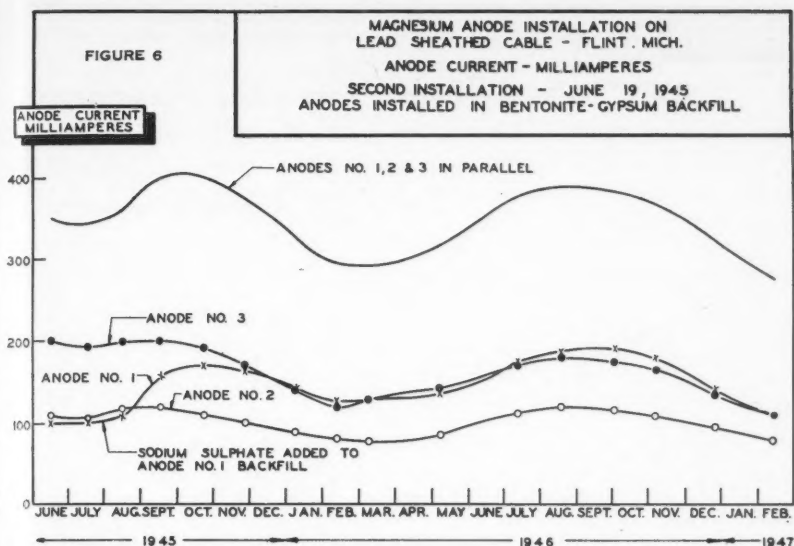
3) Frequent recharging with chemicals would be necessary because of dilution or occasional pumping of the manhole.

Accordingly, the magnesium anode installation was made some seven feet out from the duct and approximately opposite (see arrows, Figure 3) the section of duct showing the lowest cable-to-duct slug resistance. The first of these installa-

tions, made July 26, 1944, comprised three 13.5-pound anodes cored with a spiral of galvanized iron wire. Two of these anodes, numbers 1 and 2, were a magnesium alloy, whereas anode number 3 was cast from pure commercial magnesium. These were installed on about 20-foot centers in holes five feet deep, which were backfilled with a mixture of earth and ordinary salt (NaCl), about 20 pounds of salt being used around each anode. Measurements of current flow and anode-to-ground resistance made soon after installation gave the following data:

Anode No.	Resistance to Ground, Ohms	Current Flow Amperes
1	4.5	0.220
2	3.6	0.260
3	3.4	0.270
1, 2 & 3 in parallel	1.25	0.530

The effectiveness of the installa-



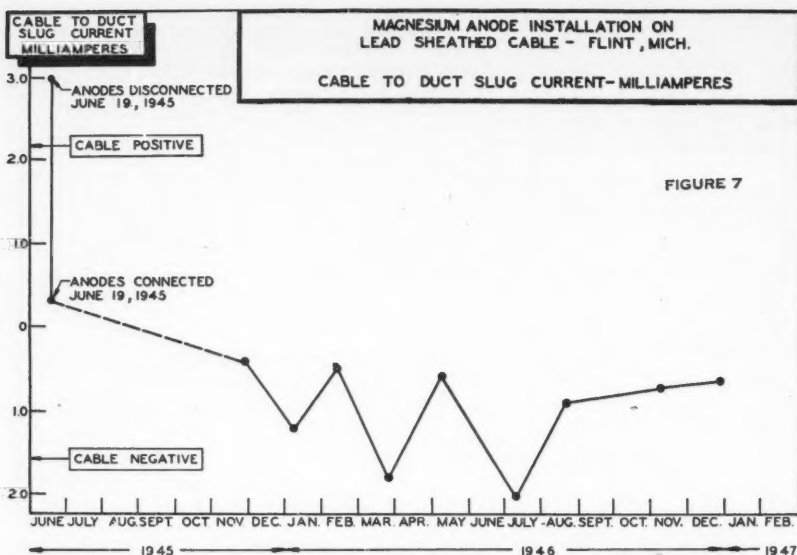
tion is evident from the duct survey of August 24, 1944, shown in Figure 3. Although anode current output had then dropped to 450 milliamperes, the cable-to-duct slug current had been reversed over the entire 100-foot run of low resistance duct, the cable sheath now being negative to the test slug. In the ensuing fall and winter, however, anode current flow decreased steadily, as is shown by Figure 4, but, contrary to expectations, an increase in current flow was not observed in the spring and summer of 1945. Further investigation revealed a steadily increasing anode-to-ground resistance, indicating that the soluble salt backfill was being leached away too rapidly by rainfall and ground water. On June 19, 1945, another duct survey was run, with the result shown in Figure 5. The cable-to-test slug current had again reversed and a peak current of as much as 2.0 milli-

amperes was observed. Measurements on the anode installation at this time gave the following information:

Anode No.	1	2	3	All
Current, ma.	33	40	140	200
Volts to cable.....	.85	.93	.87	...
Resistance to cable,				
ohms	17.0	14.5	5.0	3.0
Cable-to-ground resistance = approxi-				
mately 0.5 ohms.				

The anodes of the above installation were then dug up to make way for a second trial installation. Anode number 3 was found to be almost completely disintegrated by local corrosion, whereas anodes number 1 and 2 were noticeably corroded but had not diminished appreciably in size. These anodes were subsequently found to have lost some two to three pounds in weight.

A second installation was made on June 19, 1945, using three high purity Mg-6%Al-3%Zn alloy anodes having galvanized iron pipe cores. Anode weights ranged from 17.5 to



18 pounds. These were placed in the original anode holes, after deepening them to about six feet, and backfilling with a gypsum-bentonite mud, prepared by mixing bentonite and gypsum (proportions 3:1) with water. About twelve gallons of mud were used in each hole.

Tests made immediately after the new anodes were backfilled gave the following data:

Anode No.	1	2	3	All
Current, ma.	100	110	200	350
Volts to cable.	1.1	1.1	1.15	...
Resistance to cable, ohms	9.0	8.0	4.0	2.5

The immediate effect of this installation, as shown in Figure 5, was to reduce the peak cable-to-test slug current from some 3.0 milliamperes just before installation to about 0.3 milliamperes with 350 milliamperes flowing to the new anodes. By leaving the test slug in the duct at the point of maximum current flow and making periodic measurements, the

subsequent trend of cable-to-test slug current was followed. This data, plotted in Figure 7, shows the drop in cable-to-slug current occurring immediately after installation as well as the reversal in polarity which took place sometime in the five months elapsing before the next current reading was made.

Since November of 1945 there have been minor fluctuations in slug-to-cable current, but to date the cable has been maintained consistently negative with respect to the slug.

Aging of the freshly abraded surfaces of the test slug and the attendant change in its potential together with cathodic polarization of the cable sheath probably account for most of the reversal of polarity noted above, although anode current flow continued to increase for several months after installation.

As is indicated by the anode cur-

rent flow record shown in Figure 6, the performance of the second anode installation has been markedly superior to that of the first installation. After dipping slightly from the 350 milliamperes obtained initially, the total current rose to a maximum of 400 milliamperes in October of 1945. Thereafter a periodic seasonal variation was observed, with a maximum current of about 400 milliamperes being attained in early fall as compared with a minimum of some 280 milliamperes in late winter.

The above current cycle is believed to correlate with seasonal changes in soil temperature but it appears to have no very marked effect on the continuity of protection, probably because of compensating seasonal changes in the cable sheath-duct slug circuit.

This installation, after some 21 months of service, has thus far shown no evidence of polarization or diminished current flow not attributable to seasonal or climatic soil changes. The improvement over the earlier installation is attributed primarily to the use of a more stable backfill composition.

Conclusion

The above installation is a practi-

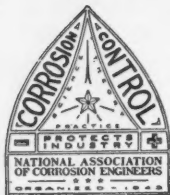
cal demonstration of the potentialities of the magnesium anode as a means of mitigating electrolytic corrosion on lead cable sheath. Electrical duct survey methods show that protection of the cable sheath has been established and continuously maintained for a period of nearly two years, and the anode current log gives assurance of continued protection for the life of the anodes. When installed in a stable backfill, the magnesium anode offers a portable galvanic current source substantially free from anodic polarization. Because of its high potential, current flows of a practical size are developed with a minimum number of installations.

Acknowledgment

The writers wish to thank Mr. R. L. Rayner, Mr. A. J. Kelb and other employees of the Michigan Bell Telephone Company, who obtained the data and supplied the information which made this paper possible. Their wholehearted cooperation and painstaking work are very much appreciated. Data plotted in figures 2-7 were furnished through the courtesy of Mr. Rayner.

References

1. Gorman, L. J., Electrolysis and Corrosion of Underground Power System Cables. *Elec. Engr. Trans.* **64**, 329-336, (1945) June.
2. Mears, R. B., and Brown R. H., A Theory of Cathodic Protection, *Trans. Electrochem. Soc.* **74**, 519-531 (1938).
3. Miller, M. C., Cathodic Protection of Buried Metals, *Elec. Light and Power*, **25**, 92-96, (1944) June.



A Message from Your President

I WISH TO TAKE this opportunity to express my appreciation for the confidence you have shown in electing me to act as President of our Association for the coming year, and to assure that I will not spare time or effort in an attempt to help you make this a very successful year for our Association. I believe all the other officers and directors can be depended upon to give freely of their time and talent for the benefit of the Association. However, each of us must realize that no Association, particularly one such as this, which is still very much in the development stage, can hope to continue successful unless a large percentage of the individual members are constantly and continually working to help that Association realize those objectives for which it was organized.



Your officers and directors can do little more than correlate and summarize the results of the work done by the individual members at large, on whose efforts depend the real success of the Association. For these reasons I would like to suggest that each of you budget, allocate, and devote at least one hour each week on constructive work for your Association. If you will do this, I assure you the coming year will be unusually successful for the National Association of Corrosion Engineers.

If any member is at a loss to know how he can best serve his Association, I suggest that he get in touch with any one of our officers or directors. However, if you wish, you can take active part immediately in the organization of local sections. I, personally, feel that local section organizations, with frequent intimate discussions between operators and technical personnel, will ultimately be the most worthwhile and productive part of our Association's work. Within a few years it is hoped that a local section will be functioning in every community in the United States where ten or more individuals interested in corrosion control are located.

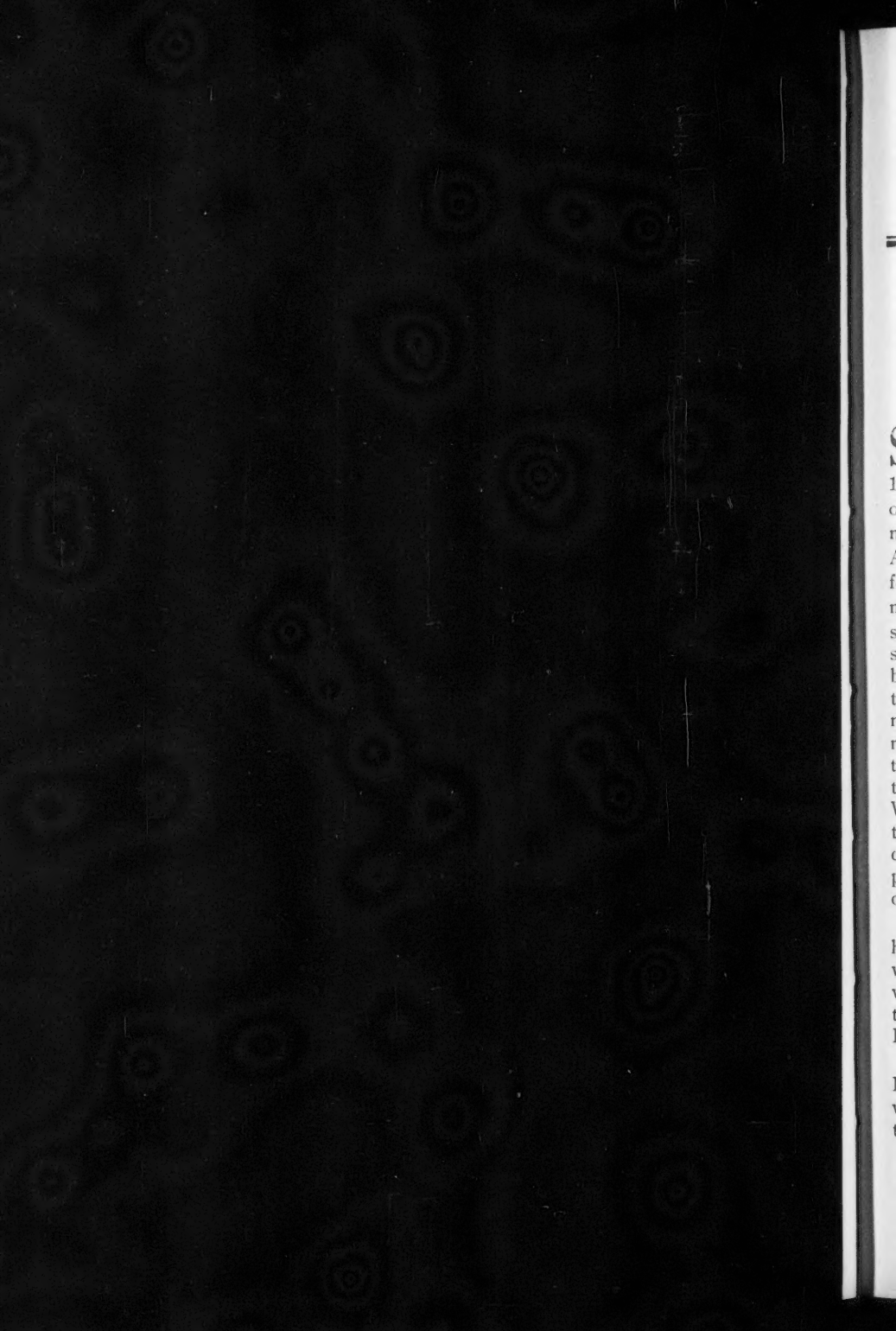
The first step in forming a local section is to get a group meeting regularly as an informal corrosion discussion group. As soon as this group has ten National members, they should then apply to their respective Regional Division for recognition as a local section of NACE. All officers of such local sections should, of course, be members of NACE, but all individuals interested in corrosion control may become members of local sections, and should most certainly be encouraged to attend meetings regularly and take an active part in the work.

G. R. Olson,
President.

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NACE News

Report of the Committee on Anodes for Use With Impressed Current

SUBSEQUENT to a meeting held in Shreveport, La., January 31, 1947, to discuss possible field tests on carbon and graphite anodes, the matter was referred to the National Association of Corrosion Engineers for consideration as a possible permanent technical committee sponsored by the Association. As a result, the suggestion was discussed by the Technical Practices Committee of NACE at their April 7, 1947, meeting in Chicago, Ill. The Technical Practices Committee decided to initiate a suitable committee, with the formal name of "Anodes for Use With Impressed Current." The function of this new committee is to handle all anode problems in cathodic protection where current from an outside source is used.

The studies are to include the behavior of anodes in fresh water, sea water, and chemical solutions, as well as underground. The committee will work under the Technical Practices Committee.

Donald H. Bond, of The Texas Pipe Line Company, Houston, Texas, was appointed Chairman, and given the authority to appoint other mem-

bers of the Committee, who are as follows:

W. A. Broome, Louisiana-Arkansas Gas Co., Shreveport, La.

Lee N. Spinks, United Gas Pipe Line Co., Shreveport, La.

J. P. Oliver, National Carbon Co., Cleveland, Ohio.

O. C. Roddey, Interstate Natural Gas Co., Monroe, La.

Derk Holsteyn, Shell Oil Co., Inc., Houston, Texas.

R. D. McClintock, Colorado Interstate Gas Co., Colorado Springs, Colo.

A. W. Peabody, Ebasco Services, Inc., New York, N. Y.

All of the above members accepted appointment, and are interested in furthering the objectives of the committee. No specific limit has been set on the total number of committee members, so additional members may be appointed from time to time when found appropriate to handle various activities. In this connection, the Committee is open to suggestions as to additional members, and also for specific problems to be investigated.

Immediately following the action of the Technical Practices Committee

in creating the Committee on Anodes for Use With Impressed Current, a meeting of the new group was held on April 8, 1947, in Chicago. Those present were Messrs. McClintock, Broome, Roddey, Holsteyn, C. W. Evans (representing Lee N. Spinks), Chairman Bond, and the visitors, A. W. McAnney, The Texas Pipe Line Co., Houston; and W. M. Clifton, Canadian River Gas Co., Amarillo, Texas.

After the meeting was called to order, Mr. Holsteyn described and showed photographs of tests he had conducted on carbon, graphite and steel pipe anodes. These data are now a part of the Committee records.

The decisions and suggestions¹ made by a temporary Committee formed on January 31, were discussed and accepted by the present committee, and the following additional decisions made and accepted:

- 1) All members of the committee are to be furnished copies of all data pertinent to committee activities.
- 2) The National Carbon Company is to furnish anodes and backfill materials prepaid to destination for comparative tests on carbon, graphite and steel anodes. The cooperating companies are to furnish locations, cable, labor, power and other incidental materials for installing the anodes and conducting the tests.
- 3) The National Carbon Company, through J. P. Oliver, agreed to initiate and conduct appropriate laboratory tests in respect to current density limitation on anodes.

- 4) For anode and pipe-to-soil potential readings, it was agreed that the copper sulphate electrode would be used as standard.
- 5) In using this electrode, it was further decided that, where practical, the Remote Earth Method would be used.
- 6) A Standard data sheet was discussed. Mr. Oliver described one which he had prepared. After due consideration, this sheet was accepted with certain changes and modifications. Mr. Oliver agreed to prepare copies of the revised form, and furnish copies to committee members and cooperating companies.
- 7) Potential measurements to be made with appropriate instruments. For measurements of potentials to soil, a voltmeter of high internal resistance such as a Rawson, or a zero current-type instrument is to be used. For open-circuit potential readings, a Weston, Model No. 1, a Rhodes potentiometer, or a similar instrument is to be used.
- 8) Cooperating companies are asked to furnish cost figures on the respective test anode installations.

Reference

1. New Committee Formed to Study Anodes for Use With Impressed Current, *Corrosion* 3, 6, 7, News Section, (1947) June.

General Interest

The Executive Committee of NACE for the 1947-48 term under President G. R. Olson, United Gas Pipe Line Co., Shreveport, La., consists of the following members of the Board of Directors:

L. A. Baldwin, Johns-Manville Sales Corp., New York, N. Y.

F. L. LaQue, International Nickel Co., Inc., New York, N. Y.

R. B. Mears, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

O. C. Mudd, Shell Pipe Line Corp., Houston, Texas.

Mr. Mears was also reappointed Chairman of the Technical Practices Committee by the Board, and was

named a member of the Technical Program Committee for the 1948 Convention and Exhibition, to be held April 5 through 8 in the Jefferson Hotel, St. Louis. Other members of the Technical Program Committee are:

M. G. Fontana, the Ohio State University, Columbus, Ohio, Chairman.

A. Wachter, Shell Development Co., Emeryville, Calif.

F. A. Rohrman, Kansas State College, Manhattan, Kan.

F. L. LaQue, International Nickel Co., Inc., New York, N. Y.

Paris Corrosion Congress Program Arranged

HUGH J. McDONALD, Illinois Institute of Technology, Chicago, Illinois, and member of the Board of Directors of the National Association of Corrosion Engineers, reports that a communication has been received from H. Perreau, secretary of the Technical Commission on Surface Properties of Metals, Paris, France, outlining the subjects to be discussed during the International Corrosion Congress, to be held in Paris October 6 through 8, 1947.

The subjects to be discussed are as follows:

- a) Theory of corrosion—Experimental methods for the study of corrosion.
- b) Testing methods—Relation between laboratory tests and long-time tests.
- c) Correlation between corrosion and surface constitution and conditions.
- d) Intergranular corrosion.
- e) Corrosion at high temperatures.
- f) Corrosion by petroleum, lubricants, organic materials, etc.
- g) Protection of light alloys.
- h) Industrial application of corrosion-resistant metals.
- i) Practical aspects of corrosion.

A special invitation has been issued to those interested persons in the United States to present papers. Communications regarding manuscripts should be sent to H. Perreau, 209 Boulevard St Germain, Paris 7, France.

Tom L. Holcombe, Dearborn Chemical Co., Shreveport, La., Chairman of the Membership Control Committee, and **H. M. Trueblood**, Bell Telephone Laboratories, Inc., Chairman of the Policy and Planning Committee, are selecting members for the respective committees which they head. Names of all suggested members will be submitted to the Executive Committee for final approval.

L. G. Gorman, Consolidated Edison Co., New York, has accepted the chairmanship of the Electrical Industry Symposium, one of several symposia scheduled during the 1948 corrosion show. Mr. Gorman, who was co-chairman of the Electrical Symposium last year, has already issued invitations to persons in that industry to submit papers for presentation at next year's meeting.

Maynard H. Jackson, Hill, Hubbell & Co., Division of General Paint Corp., Cleveland, Ohio, has been named Chairman of the Exhibits Committee for the 1948 Convention.

Joint Corrosion Symposium

F. L. LaQUE, International Nickel Company, Inc., New York, Vice President of NACE and Chairman of the Committee on Relations with Other Technical Societies, reported during the April 10 Board of Directors meeting that plans are being completed for a joint meeting of the National Association of Corrosion Engineers and the Corrosion Division of the Electrochemical Society, to be held December 8 to 10 of this year at the William Penn Hotel in Pittsburgh, Pa. The entire technical program will be devoted to the subject of cathodic protection, and authors are invited to submit papers for presentation. Further details will be published in the August edition of *Corrosion*.

F. J. McElhatton, Panhandle Eastern Pipe Line Co., Kansas City, Mo., Past President of NACE, 1946-47, has been named co-chairman of the Regional Management Committee, which is headed by **George B. McComb**, Barrett Division, Allied Chemical and Dye Corp.

N. E. Berry, Servel, Inc., Evansville, Ind., Chairman of the Chemical Industry Symposium for the 1947 Conference, has agreed to act as co-chairman of that symposium for the 1948 show.

George A. Mills, Engineering Department, has accepted appointment as one of the co-chairmen for the Electrical Industry Symposium.

In accordance with Article XIV of the By-laws and Regulations of the South Central Regional Division of the National Association of Corrosion Engineers, the Board of Trustees of the Region approved, and authorized the establishment of the Shreveport Local Section, with officers as follows:

Chairman, **W. A. Broome**; Vice Chairman, **T. B. McDonald**; Secretary-Treasurer, **Francis Ringer**.

Members of NACE who reside in the Cleveland, Ohio, area have petitioned for recognition and installation of a Cleveland Local Section through the North Central Regional Division Chairman, **L. F. Greve**.

The British Engineers' Association, 32 Victoria Street, London S. W. I., England, announced plans for a 1947 Engineering and Marine Exhibition, to be held August 28 through September 13.

July 1947

The largest turnout to date for a Houston Section of NACE meeting developed when 60 members and guests registered for the June 18 meeting, held at the Houston Engineers' Club. The meeting was presided over by Section Chairman W. P. Noser. Donald Bond read D. B. Good's paper, "The Location and Selection of Anode Systems for Cathodic Protection Units." R. A. Brannon, O. C. Mudd and Derk Holsteyn read prepared discussions, and much impromptu discussion developed from the floor. Starr Thayer acted as conductor of a general discussion on the subject of atmospheric corrosion, during which Messrs. J. M. Moore and L. C. Perry presented interesting experiences at Dow Chemical Company's Freeport plant, including flame cleaning, use of heat in speeding up sand blasting and the use of vacuum blasting. Mr. Moore stated that Dow expends approximately \$1 million annually in combating corrosion. He also said, "... we have found no all-purpose paint. My company has 287 different types in its paint shop—far too many."

Dinner and refreshments were provided through courtesy of James E. Mavor.

Personals

M. W. Reed has been elected vice president in charge of engineering, Carnegie-Illinois Steel Corp., subsidiary of U. S. Steel Corp., Pittsburgh, Pa. He has been chief engineer of the company since 1939, and previously was vice president in charge of operations, American Steel & Wire Co., another U. S. Steel subsidiary.

D. B. Harris and J. A. Neath have

Corpus Christi Section

MEMBERS of the National Association of Corrosion Engineers who reside in Corpus Christi, Texas, are planning to petition through the South Central Regional Director, L. F. Scherer, for recognition as a Local Section, with officers as follows:

Chairman, R. W. Graves, Chicago Corp.; Vice Chairman, S. L. Richards, Jr., Rossen-Richards Co.; Secretary-Treasurer, T. Mofatt, Jr., Southern Alkali Corp.

A meeting of the group has been tentatively scheduled for July 16 in the Auditorium of the Central Power and Light Co., in Corpus Christi.

Dresser Industries, Inc., Cleveland, Ohio, has signed a \$6 million contract with the Soviet government to build a gas liquefaction plant 60 miles from Moscow, Russia.

Selenium Corporation of America is now established in its new home at El Segundo, 15 miles south of Los Angeles, Calif. The company, acquired by Vickers, Incorporated, of Detroit, Mich., a year and a half ago, thus a unit of the Sperry Corporation, produces power rectifiers for cathodic protection, miniature rectifiers and photo electric cells and allied component parts for construction of holiday detecting equipment.

been named vice presidents by the board of directors of the Humble Oil & Refining Co., Houston, Texas. Stockholders re-elected all directors of the company, who are as follows: H. C. Wiess, Hines H. Baker, L. T. Barrow, David Frame, D. B. Harris, J. A. Neath, Rex G. Baker, and H. W. Ferguson.

Walther Mathesius, president, Geneva Steel Co., a subsidiary of

United States Steel Corp., New York, has been elected a director of U. S. Steel Corp., of Delaware. Connected with subsidiary companies of the corporation since 1911, he was named vice president in charge of operations and a director of U. S. Steel Corp., Delaware, when it was formed in 1938, but left a few years later to become president of Geneva Steel Co. during its operation for the account of the government. He continued in these posts after U. S. Steel acquired the company as a subsidiary.

T. F. Olt has been named director of research for the American Rolling Mill Company, Middletown, Ohio, succeeding Anson Hayes, retired, but who has been appointed director emeritus, and who will continue active with respect to research policies of the company.

Brig. Gen. Hugh C. Minton, who directed the Production Division of the Army Service Forces during World War II, has been named production manager of Koppers Co., Inc., Pittsburgh, Pa.

C. W. Barkow has joined the staff of the Chemical Compound Co., Houston, Texas. He was formerly connected with the Office of Price Administration.

Hugh J. Fraser, vice president of The International Nickel Company, Inc., has been placed in general charge of all plant operations of the company in the United States, according to an announcement by John F. Thompson, executive vice president. John A. Marsh, assistant general manager of the Huntington (West Virginia) Works, has been

appointed Mr. Fraser's assistant, with the title of assistant to the vice president.

Mr. Fraser, vice president of the company since March of this year, had been an assistant vice president since June, 1943. He joined the Huntington Works of the company in May, 1923, and after serving for some years in various technical and operating capacities was promoted to the New York office in February, 1935, becoming assistant manager of the production department. Mr. Fraser is a native of Brockville, Ontario, and received a Bachelor of Science degree from Queen's University, Kingston, Ontario, in 1923.

Born in Lake Bluff, Ill., Mr. Marsh became associated with International Nickel as a laboratory assistant at its Huntington Works following his graduation from the University of Michigan in 1928. He was transferred to the Bayonne (N. J.) Works of the company as assistant superintendent in January, 1936. In August of the same year he became general superintendent of the Bayonne Works. He was named general superintendent of the Huntington Works in September, 1942, and in June, 1944, was promoted to assistant general manager.

THE NEWS SECTION is primarily incorporated in *Corrosion* to provide a record of the current activities of members of the Association, and to convey information of interest and value to members. All members are invited (in fact urged) to send releases, or letters, informing the editors of changes in positions, promotions, achievements, or other news items. All material should be forwarded to the Editor of *Corrosion*, 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.

New Products

Micro Metallic Corporation, 193 Bradford St., Brooklyn 7, N. Y., announces the addition to its line of stainless steel filters of a range of standard sizes of industrial gas dispersion units.

These units consist of a disc of porous stainless steel, which is welded about its periphery to a shallow stainless steel dish. The dish is welded to a standard female pipe connection. In use, the required number of pipe connections are provided at the bottom of the tank, and the spargers are then screwed into place.

The porous stainless steel elements are available in fine porosities, ranging from 5 to 65 microns. The finer grades yield a large volume of very fine gas bubbles. Flow capacities for all the grades are high, and are accompanied by unusually low pressure drops, compared with thicker and less uniform dispersion media, according to the manufacturers.

Diameters available in the porous elements are 1 inch, $1\frac{1}{2}$ inch, $2\frac{3}{8}$ inches, and $3\frac{1}{4}$ inches, and the pipe connection sizes are $\frac{1}{8}$ inch, $\frac{1}{4}$ inch, $\frac{3}{8}$ inch and $\frac{1}{2}$ inch. Special sizes and shapes can be supplied.

Detailed engineering information on the capacities of the various grades of filters are available on request.

While not exactly new, the process originated by British Ropes, Inc., and known as "BRyanizing" is recognized as one of the better methods of galvanizing steel wires and other materials of steel required to resist weathering and corrosion. In the BRyanizing method, zinc is applied by electrolytic deposition, and by this means the wire is coated with a purity claimed to be between 99.99 and 99.999 percent. The process enables zinc to be deposited upon wire at any desired thickness, without irregularities, and the coating is said to be perfectly uniform and concentric on the wire, and will neither crack nor flake. The electrolytically deposited coat was developed primarily for use in oil fields where drilling operations are conducted in or near seashore, where salt spray promotes rapid corrosion, and in the tropics where heat and humidity actively promote deterioration of protective coatings.

Corrosion-resistant aluminum-clad conduit designed for overhead steam, oil, hot water and brine distributing lines is being manufactured by the Ric-Wil Co. in Cleveland.

Any desired section of pipe is used, insulated with cylinders of asbestos pipe covering and coated with asphalt. The pipe is wrapped tightly in a sheet of aluminum which makes a good bond when used with asphalt.

F. J. McElhatton's Farewell Address as President of National Association of Corrosion Engineers

AS PRESIDENT of the National Association of Corrosion Engineers, it is gratifying to see so many people present at our third annual Conference. It is proof that the Association has matured as an active force in the progress and development of combating corrosion. The eight to ten men who met in Houston, Texas, in October, 1943, and started this organization, of course, hoped that the new venture would grow and would enlist the interest and support of all industry. The idea, and the work done by the Association has proved sound, as is demonstrated by our present membership of more than 1000 individuals, representing *Water, Oil, Communications, Electrical, Chemical, Natural Gas, Transportation, Sanitation, Marine, and Manufacturing* industries in general.

Today we could talk about the short history of NACE. We could talk about our accomplishments and our phenomenal growth to date. But we should not dwell upon passing events and begin to reminisce. To do so would leave the impression that we, as an organization, are getting old. To be sure, such is not the case. As a matter of fact we are not yet four years of age and our big opportunities lie ahead. Some members say, and perhaps rightly so, we have

not so much as entered our first year of schooling—that our education to date has all taken place in kindergarten.

I like to think of NACE in that light. I like to think that we have honestly finished our preliminary work—that a solid, firm foundation has been laid—that the foundation is so arranged as to permit the annexation and maintenance of many accomplishments yet to be achieved. I like to think of our growth in membership, our expansion in technical committee work, and the quality of leadership among those who will succeed the retiring officers.

In a short review of the past, it would be unfair to say the progress of NACE to date has been effected without hardship. Only through the determined will to do of those of the pioneering group could we have reached our present position in the improvement of our Association. These men, all of whom you know, simply would not let any obstacle, however large, become a barrier to a better and longer life for metallic structures. To each and all of these men who conceived the idea of NACE, planted the seeds and caused them to grow and thrive, we owe a great debt of gratitude.

So tomorrow we start to school. In many respects I'm sure that is true. What we may learn and what we master depends entirely on the way

Presented before the General Assembly at the Annual Meeting of NACE in Chicago, Ill., April 7-10, 1947.

we continue to apply ourselves. With us, in the same classroom, will be management, operators, teachers and technicians. All of us must work together as a group, live together and above all else, remain together. Our whole future, as a team, depends on the interference one runs for the other.

In actuality, we of NACE must study to sell and save. Yes, we must sell more of those in the positions of management on the value of our Association. We must use all our ingenuity to make our supervisors realize and appreciate the fact that all metals are derived from natural resources. The conservation of natural resources will, in the end, control the destiny of industry. We should, at the very beginning of our accredited school work, condemn the idea of creating construction through the ravages of destruction. That sort of reasoning can and will help the whole nation. That sort of reasoning can and will initiate the savings so badly needed in industry.

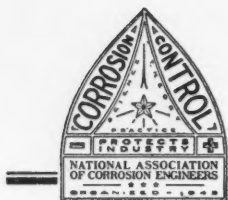
When management, both in operations and manufacturing, is fully "sold" on our philosophy of protection and savings, the proper financing for our future research and development will come. The operators will be happy to cooperate for they will soon see their day's work reduced from tiresome gruelling repairs to smooth, effective and economical operations. They will gradually be made to know that it is only normal for equipment to wear out; but a shame and disgrace for permitting the same equipment to rust out.

Together with this attitude and spirit of coöperation will come an easier task for those in the laboratories of our schools, institutes, and plants. Real honest to goodness accomplishments can be completed in a manner consistent with industrial peace and harmony.

With these opportunities before us, I know every one of you will want to take an active part. I know you will meet every challenge which may confront you and regardless of what side of the fence you are on, I know you will do something about it.

Some day in the not too distant future, I am certain our thoughts and recollections will prove to be subjects of keen interest. Especially is this true when you stop to think that five years hence the active, corporate, and associate memberships will have grown into several thousands, and some form of corrosion control standardization has become a reality. At that time, I am sure all of us will be glad to know that we helped plant a flower where we thought a flower would grow. I am satisfied that we have been tested and are recognized as a stable, permanent organization which will make great strides in defeating the common enemy to industry—corrosion.

I want to express my deep appreciation for the confidence placed in me by selecting me as your president for the past year. Your help has been invaluable; and to the directors and to you I say—"Thanks for the honor, thanks for your help!"



Corrosion Previews

Resistance of Aluminum to Corrosion in Solutions Containing Various Anions and Cations

By A. B. McKEE and R. H. BROWN
Research Laboratories
Aluminum Co. of America, New Kensington, Pa.

The effect of various anions and cations on the rate of corrosion of aluminum in solutions of various acids and bases at room temperature has been investigated. It was found that with the ions studied in acid solutions the rate of corrosion is influenced to a greater extent by the anions than by the cations.

The corrosive effect in increasing order of anions in acid solutions is acetate, phosphate, sulfate, nitrate, and chloride. Of the two cations investigated in acid solutions, the ammonium cation is slightly more corrosive to aluminum than is the sodium cation; however, this difference is not significant.

Aluminum is resistant to corrosion by acetic acid at all concentrations both in the presence and in the absence of sodium or ammonium salts of this acid. Aluminum is also resistant to corrosion by mineral acids in concentrations up to 0.001 normal, either in the presence or in the absence of the sodium or ammonium salts of the corresponding acids.

In ammonium hydroxide solutions either with or without chloride, nitrate, carbonate, acetate, sulfate, and chromate salts of ammonia, aluminum is resistant to corrosion. Aluminum is resistant to attack in sodium hydroxide solutions up to 0.0005 normal, either in the presence or in the absence of chloride, sulfate, nitrate, and acetate salts of sodium. However, in

the presence of chromate anion (1.0 normal Na_2CrO_4) aluminum is resistant to corrosion even in concentrations of sodium hydroxide as strong as 0.1 normal.

Aluminum is resistant to sodium carbonate solutions up to 0.001 normal concentrations, both in the presence and in the absence of sodium chloride, but in higher concentrations the behavior is similar to that of sodium hydroxide solutions. The resistance of aluminum to corrosion in any given solution appears to be influenced to an appreciable extent by the stability of the oxide film and by the solubility of the corrosion products.

This section was established in Corrosion to give summaries of the papers that were presented during the 1947 NACE Corrosion Conference in Chicago. Many of these papers, after being processed by the Publication Committee, will appear in full, together with illustrations, in later editions of Corrosion.

Arsenic as a Corrosion Inhibitor in Sulfuric Acid

By A. WACHTER, R. S. TRESEDER and
M. K. WEBER

Shell Development Company, Emeryville, Calif.

Trivalent arsenic compounds, such as arsenic trioxide or sodium meta-arsenite, behave as effective inhibitors of corrosion of carbon steel by hot, strong sulfuric acid under many conditions that may be employed in petroleum processes. Arsenic has been shown to be capable of substantially preventing corrosion of steel by acid concentrations in the range from 50 to 72 percent sulfuric acid at temperatures up to 85° C., even under high velocity flow conditions. It is less effective as an inhibitor in acid strengths around 88 percent H_2SO_4 . The concentrations of arsenic needed to suppress corrosion increases as the concentration of sulfuric acid is decreased, as temperature increases, and as trace contamination of the acid with copper increases. No evidence of pitting action was detected when general corrosion was completely suppressed.

Mr. Wachter, who read the paper during the Oil Industry Symposium at the annual meeting of NACE in Chicago April 7-10, 1947, received his B. S. in chemistry in 1927 from the College of the City of New York, and his Ph.D. (physical chemistry) in 1930 from the University of California. His thesis was on thermodynamics of molten salt solutions, which he prepared in collaboration with Prof. J. H. Hildebrand. A National Research Fellow, Mr. Wachter worked with Prof. Linus Pauling at California Institute

of Technology from 1930 to 1931; and undertook research on thermodynamic properties of solid solutions of salts and of metals during 1931-32 at the Johns Hopkins University with Prof. D. H. Andrews. In 1932, Mr. Wachter joined Shell Development Co., doing research work on chemical petroleum processes, and in 1938 was made head of the Corrosion Research Department of Shell, with research on all types of corrosion problems of the petroleum industry, and related chemical industry. His especial interest is in possibilities of employing corrosion inhibitors for protection of process equipment. E.g. developed successfully used sodium nitrite treatment process for prevention of internal corrosion in petroleum products pipelines. Recently he was given the Naval Ordnance Development Award for development of volatile inhibitors of corrosion used in preventing corrosion of packaged or stored steel.

Mr. Treseder joined Shell after receiving his B.S. in Chemical Engineering from the University of Utah in 1938. Engaged in analytical research until 1940, he joined the Corrosion Department staff that year to do research on various corrosion problems encountered in the petroleum industry. Mr. Weber received both the B.S. and M.S. degrees from Washington State college. He joined Shell upon leaving college in 1938, to do production research. In 1942, he became affiliated with the Corrosion Department of Shell to do research, with special emphasis on corrosion problems in process equipment.



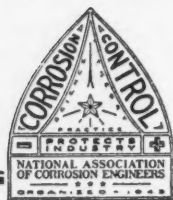
R. S. Treseder



A. Wachter



M. K. Weber



Corrosion Abstracts

ATMOSPHERIC CORROSION

Atmospheric Rusting of Low-Alloy Steels. H. R. COPSON, International Nickel Co., Iron & Coal Tr. Prot., **3**, 8, 22 (1946) Oct.—Dec. Rev. **153**, 276 (1946) Aug. 16 Corr. & Mat.

Abstract of a report submitted to American Society for Testing Materials. Based on exposure tests in industrial and marine atmospheres, a new theory on rust formation has been developed. Author concludes that there is no doubt that increased corrosion resistance is accompanied by increased sulphate in the rust.—INCO.

Magnesium. R. R. ROGERS, D. A. TETU & H. LIVINGSTONE, Metal Ind., **70**, 9-10 (1947) Jan. 3.

Experimental results indicate that magnesium and its alloys offer good resistance to corrosion when exposed to inland, indoor and outdoor atmospheric condition, but much less in marine atmospheres.—BLR.

Air and Moisture in Turbine Castings. S. M. ELONKA, Mar. Eng., **51**, 11, 111 (1946) Nov.

Discusses the main cause, which is the presence of oxygen and moisture, and its prevention, for rusting and corrosion in the interior of turbine castings.—INCO.

BEARING CORROSION

Effect of Crankcase Ventilation on Engine Deposits. H. L. MOIR & H. L. HEMINGWAY, Pure Oil Co. SAE, **1946**, Preprint, 19 pp. (Mimeogr.)

Corrosion of engine parts due to contamination of engine oils by acids originating from sulfur in fuel, etc., eliminated or reduced by correct crankcase ventilation. Types and examples of deposits formed, various ventilation systems, and results of tests determining the effect of crankcase ventilation on corrosion discussed and shown. Corrosion of copper and steel strips suspended in crankcase vapors drawn from engine operating under conditions modified to eliminate crankcase ventilation described. In other tests showing effect of restricted ventilation on engine cleanliness (Chevrolet), weight loss of alloy bearing inserts doubled in runs with no ventilation. In watching for cases where additional ventilation will be of service, varnish deposit in oil-fill gap, excessive crankcase dilution, water in crankcase oil and corrosion of hard alloy bearings or other engine parts in engines operating at low temperature are indications. Several crankcase designs are shown.—INCO.

CATHODIC PROTECTION

Selenium Rectifiers for Cathodic Protection. W. F. BONNER, Fed. Telephone and Radio Corp., Corr. 2, 249-260 (1946) Nov.

Selenium rectifiers described and shown; size and current capacity for heavy duty rectifiers tabulated; graphs show static resistance curve, voltage drop, effect of temperature on output voltage, efficiency, and operating time. Typical rectifier circuit connections and circuit data fabricated and drawn.—INCO.

Attenuation of Forced Drainage Effects on Long Uniform Structures. ROBERT POPE, Corr. 2, 307-319 (1946) Dec.

Approximate equations have been developed which are useful in prediction of effects of forced drainage on cathodic protection of underground metallic structure. The soil and structure characteristics which enter into the equations are discussed. Charts show some of the relationships.—BLR.

CHEMICAL CORROSION

Corrosion of Metals in Chloroform and Carbon Tetrachloride. M. STAUB, Ann. chim., 1, 12, 105-156 (1946); Chem. Abs., 40, 7140-7141 (1946).

The object was the determination of the mechanism of corrosion of metals by nonconducting solvents. Solvents investigated are: dry and wet chloroform, ethyl alcohol, and carbon tetrachloride. The metals submitted to corrosion are: aluminum, iron, tin, zinc, copper, and lead. A revue of data concerning the intrinsic properties of the solvents and their effect on metals, a qualitative study of corrosion carried out in stagnant conditions at ordinary

temperature and the study of the effect of humidity and light in the presence and absence of air, and a quantitative study carried out in conditions similar to those of the qualitative study is given. Corrosion is measured by the amount of gas evolved during the reaction. The general conclusions are: 1) In the absence of oxygen, corrosion is always much more important in wet than in dry solvents; 2) In the presence of oxygen, the effect of water depends on the nature of the metals; corrosion of iron and tin is accelerated by the presence of water, while that of aluminum and copper is inhibited; in the case of lead, the effect of water depends on the nature of the solvent; and 3) Light affects corrosion of iron but not other metals. No general mechanism of corrosion could be established. In certain cases, the attack seems to be due to hydrogen-chloride liberated by hydrolysis of solvent; in other cases, either a direct reaction between the solvent and the metal, or a formation of intermediary organo-metallic compounds appears to be the most probable mechanism.—INCO.

The Gremlin of the Sewage Plant. W. A. SPERRY, Sewage Works Eng. & Mun. San, 17, 356-359 (1946) July; Corr. & Mat. Prot., 3, 7, 28 (1946) Aug.-Sept.

Sulfur, particularly in the form of hydrogen sulphide in the sewage gas, is the worst offender in sewage-treatment plants. At Aurora, Ill., many samples of building hardware exposed in the plant, wrought-iron gas-pipes, and electrical equipment corroded where the humidity was high. Laboratory tests were then made on the effect of hydrogen sulphide on nine aluminum, nine ferrous, 21 non-ferrous, and

three miscellaneous metal samples during a period of 33 months. Results given.

Cracks in Dished Heads. Locomotive, **46**, 48-49 (1946) Apr.; Corr. & Mat. Prot., **3**, 7, 29 (1946) Aug.-Sept.

Describes failure of the head of a tank after only a few months' use in a filtering tank. The sharp knuckle radius of the head and presence of water within the tank caused cracking as a result of corrosion fatigue.

Corrosion-Resistant Processing Equipment of Clad Steels for Chemical and Allied Industries. E. C. GOSNELL, Luken Steel Co., Corr. **2**, 287-306 (1946) Dec.

The fabrication, selection, design, and uses of clad steel corrosion-resistant processing equipment in a number of industries are discussed. Clad materials are ideally suited for the large dimension equipment in the petroleum industry.

Nitric and Sulphuric Acids: (Use of Non-Ferrous Metals in) Transport and Handling. Ind. Chem., **20**, 234, 345-352; 235, 416-422; 236, 475-480; 237, 537-543 (1944); Ordnance Factories and the Ministry of Supply, Memorandum No. 13; J. Inst. of Met. & Metall. Abs., **13**, 354 (1946) Oct.

The transport and handling of nitric and sulphuric acids are reviewed. Non-ferrous metals and alloys used for pump or tank linings, valves, and other purposes include aluminum, lead, tellurium-lead, regulus metal (lead containing 12-15% antimony), R. 55 alloy, and Everdur; the special applications of these are indicated.—INCO.

Effects of an Increase in the Concentration of Ethylene Dibromide in a Leaded Fuel on Lead Deposition, Corrosion of Exhaust Valves, and Knock-Limited Power. B. A. MULCAHY AND M. A. ZIPKIN, 5 pages. June, 1945; National Advisory Committee for Aeronautics, Washington. (Wartime Report E-43.)

Hot corrosion of the crown of the exhaust valve has been found to be one of the principal causes of exhaust-valve failures. This hot corrosion is a result of the action of lead oxide deposited on the head of the valve during the combustion of a fuel containing tetraethyl lead. In order to prevent formation of these lead deposits within the cylinder, ethylene dibromide is added to the leaded fuel. The function of ethylene dibromide is to react with lead to form volatile compounds that will be scavenged with the exhaust gases. When ethylene dibromide in excess of the amount theoretically required was added, corrosion of the exhaust-valve crown and the material deposits on the piston and spark plugs were reduced.—BLR.

Some Aspects of the Corrosion of Aluminum. P. F. THOMPSON, J. Council Sci. Ind. Res. (Australia), **19**, 157-165 (1946) May.

The relation of corrosion of aluminum to film formation is discussed, and certain electrochemical measurements are reported. It is shown that hydrogen evolution can occur from aluminum in neutral solutions.—BNF.

Mechanical and Metallurgical Control of Sulfuric Acid Corrosion in Petroleum Processes. E. R. WILKINSON, Standard Oil Co. (N.J.), Paper, ASME, Tulsa (Oct. 7-9,

1946); abstr. Oil & Gas J. **45**, 23, 96 (1946) Oct. 12.

Principal factors influencing sulphuric acid corrosion rates, i.e., concentration, temperature, oxygen content of fluid, velocities and turbulence, and electrolytic action are discussed. Occasionally black acid from an operating unit has been found less corrosive than white acid for the same concentration range. Copper bearing alloys are corroded less by acid which has been heated just enough to expel dissolved oxygen. Sulfuric acid corrosion, especially in auxiliary equipment used in acid treating and sulfuric acid alkylation, requires the most advanced mechanical and metallurgical control methods. The most corrosive-resistant materials available must be used for acid-concentrating units.

Chemical Corrosion Resistance of Lead. Corr., **2**, 330-3 (1946) Dec.; Lead, **16**, 4, 4-5 (1946).

A partial list of chemicals used in the process industries and brief comments on the reactions they may be expected to have with lead is given as a general guide in the selection of materials of plant construction.

Talking Shop—Acid Touch. Am. Mach., **90**, 24, 107 (1946) Nov 21.

Checkup of corrosion failure of fuses in war factory led to discovery that female perspiration turns acid during the menstrual period. Similar case was reported in welding stainless-steel exhaust manifolds where assemblies emerged from annealing furnaces with corrosion-pitted surfaces. Use of gloves is indicated.—INCO.

Corrosion of Coke Cars. W. W. STEVENSON, Gas World, **125**, 65-74 (1946); Brit. Abs., **BI**, 314 (1946) Oct.

Coke cars at Thurcroft Coke Ovens are subject to considerable mechanical stresses and to corrosion by coke quenched with salt water (CaCl_2 1.25%). The life of the bottom plates was increased from 14 to 25 months by replacing mild steel by "Corten," containing carbon 0.07%, chromium 1.0%, copper 0.42%, silicon 0.87%, manganese 0.23%, phosphorus 0.156%, and sulfur 0.033%.—INCO.

Chemical Engineering and Tar Products. B. SCOTT, Chem. Tr. J., **119**, 466-468 + (1946) Oct. 18.

In work on heat transfer, fractionation and corrosion by the Midland Tar Distillers, Ltd., a standard corrosion test was developed with the corrosion index for cast iron when using tar containing 0.1 normal sodium hydroxide as standard for grading materials according to their potential value in resisting corrosion. Principal corroding agent is inorganic (ammonium) chloride. There is serious risk of mild steel tube failure towards the outlet of the radiant section after 38-48 hours. As an interim solution the use of stainless steels reduced corrosion in the radiant bank of the tube still, these having a life of 7 years, under prevailing conditions. In the column, special cast iron of the Audcoloy type was used with success and had a much greater life than cast iron. Condenser tubes of nonferrous alloys are being investigated on the rerun stills.

—INCO.

Corrosion of Feed Screws of Small Underfed Stokers. R. A. SHERMAN, J. F. FOSTER & D. A. HINCKLE, Bituminous Coal Research, Inc., Tech. Report No. 9; Battelle Mem. Inst. Fuel Res. Lab., 23 pp. (1946) May.

Conditions favorable for corrosion

of stoker screws and methods of prevention are described. Effects of temperature, moisture content of coal, acidity of coal, calcium chloride treatment and reversal of flow of gases on corrosion of stoker screws were studied. Data on release of hydrogen-chloride from calcium chloride are also presented.—INCO.

Acetic Acid vs. Materials of Chemical Plant Construction. Part II. Chem. Eng., **53**, 205-206+ (1946) Dec.

Final portion of a symposium in which typical materials of construction are evaluated for service involving acetic acid. Includes chemical porcelain; steel containing 24% nickel, 20% chromium and 3.0% molybdenum; Hastelloy; lead; high-silicon iron; chemical stoneware; rubber lining; nickel and nickel alloys.—BLR.

Nickel and Nickel Alloys for Handling Salt and Brine Solutions. Process Inds. Quar., **9**, 3, 5 (1946).

Annotated illustrations of plant handling various types of solution in which salt is an integral constituent.—INCO.

Acetic Acid vs. Materials of Chemical Plant Construction. Parts I and II. Chem. Eng., **53**, 11, 253-254 + (1946) Nov.; Chem. Eng. **53**, 12, 205-206 + (1946) Dec.

Symposium by manufacturers evaluating their product for acetic acid service. Articles as follows: Carbon, Graphite, Karbate, by E. S. Malkin (Nat'l Carbon Co.); Aluminum Alloys, by E. D. Verink, Jr. (Alcoa); Durimet and Chlorimet, by W. D. Staley (Duriron Co.); Glass Lined Steel, by O. I. Chromann (The Pfaudler Co.); Silver, by L. C. Bur-

man (Baker & Co., Inc.); Tantalum, by F. L. Hunter (Fansteel Metall. Corp.); Chemical Porcelain, by J. S. Chowning (Lapp Insulator Co.); Worthite, by W. E. Pratt (Worthington Pump & Mach. Corp.); Hastelloy, by C. G. Chisholm (Haynes Stellite Co.); Lead, by H. M. Church (Lead Industries, Assoc.); High-Silicon Iron, by W. D. Staley (Duriron Co., Inc.); Chemical Stoneware, by F. E. Herstein (Gen. Ceramics & Steatite Corp.); Rubber Lining, by O. S. True (U. S. Rubber); Nickel, Nickel Alloys, by W. Z. Friend (Inco).

Among wealth of data presented, it is mentioned that: Durimet T and 20 are resistant to both crude and pure acetic acid; Worthite is satisfactory; Hastelloy alloys are suitable for high temperature applications and with vapor, whereas Types 304 and 316 stainless are satisfactory at normal temperatures.—INCO.

COATINGS

German Antifouling Compositions. J. N. AGAR, CIOS 1945. Item 22, File 26-29, 5 pp.; Brit. Abs., **B-11**, 427 (1946) Nov.

Attempts to reduce the amounts of copper and mercury have led to the use of organic compounds of mercury and zinc. It is suggested that as the majority of surfaces (metals, corrosion products, etc.) to which the organisms attach themselves are negatively charged, fouling will not ensue if the surface is positive. Preliminary trials with Wofatit (a synthetic base-exchange material), in the form of plates are noted.—INCO.

Corrosion of Metals. Part V. Corrosion of Tinplate (Continued).

Sheet Metal Ind., **23**, 1951-1960 (1946) Oct.

Briefly outlines behavior of different types of iron with special reference to the conditions likely to obtain in tin cans. Considers the relative merits from the point of view of corrosion of hot-dipped and electro-deposited tin, and also the relative corrosion resistance of tinplate compared with untinned lacquered steel.

—BLR.

New Developments to Combat Corrosion in Paper and Pulp Industries. K. P. Chamberlain, Paper Tr. J., **123**, 126 + (1946) Oct. 10.

Discusses use of neoprene, nitrocote, and durofilm as coating materials, and a rubber pipe joint which eliminates the present flanged fabricated pipe and fittings.—BLR.

Marine Corrosion and Fouling. Part I. H. W. RUDD, Paint Mfr., **16**, 347-352 (1946) Oct.

The various types of fouling organisms are described and classified, together with information concerning their occurrence, effect on materials, susceptibility to poisons, etc. Losses caused by ship-bottom fouling are outlined. Includes photographs of organisms. 10 ref.—BLR.

Marine Corrosion and Fouling. Part III. W. RUDD, Paint Mfr., **16**, 431-34 (1946) Dec.

Non-organic poisons investigated for use in antifouling paints are classified into four groups—useless, moderately effective, effective, and outstandingly effective. The latter includes thymol, o-tertiary amyl phenol, o-cresol, cinnamaldehyde, and tar base (boiling at 260-263° C.). The mechanism of antifouling paints in general against marine organisms is discussed and the fallacy

in the use of a "toxic index" for such paints is pointed out, since the relationship will not hold if all paints tested are not made on an identical base. Inert pigments apparently have little effect on the effectiveness of antifouling agents but iron or rust seem to exercise a depressing effect, particularly on copper. The general "efficacy of commercial antifouling compositions" is reviewed briefly.

Houston Club Report on Heat-Resistant Finishes. Am. Paint J., **31**, 18-21 (1946) Nov. 8.

Describes results of tests on about 50 conventional coatings, the test on an unconventional product, the tests on a standard, and the correlation of heat tests on the apparatus used with two other series of heating and weathering tests. Those coatings which maintained a good film after heating up to 800° F. were given a weather test. Finally, if the coatings weathered well, they were applied to actual operating equipment.—BLR.

New Surface Treatment of Aluminum (Alodising). J. ANTHONY, Iron Age, **158**, 23, 64-66 (1946) Dec. 5.

An immersion treatment devised by the American Chemical Paint Co. (no details given), which is said to give a good protective coating on aluminum; also good basis for painting.—BNF.

Non-Ferrous Metals Aid in Steel's Use. J. LEVIN, Dom. Com., **33**, 37-40 (1945); J. Inst. of Met. & Metall. Abs., **13**, 420 (1946) Dec.

The role of nonferrous metal coatings on steel is described and a general summary of the use of tin, nickel, zinc, chromium and other metals that are plated, sprayed, or clad on steel is given.—INCO.

Chromuberzuge Als Korrosionsschutz (Chromium Plating as Protection Against Corrosion). WERNER AND LWOWSKI (PB 41442) I. G. Metalluko Rept. (Jan., 1940) 15 pp. M. \$1.00, P. \$1.00; Bib. Sci. Ind. Rep. 3, 577 (1946) Nov. 22.

Report gives experiments on chromium plating and on protective coatings to prevent corrosion. So far no such protection has been accomplished by chromium electroplating alone. It was suggested that it would be more economical to use chromium alloys of more than 12% chromium instead of the doubtful process of electroplating. Experiments indicated, however, that a diffusion treatment of chromium plating which was annealed electrically would improve the coating and result in high-grade platings. Only laboratory tests were performed, and further investigation is indicated. 14 microphotographs.

Interim Descriptive Statement on the Leaching-Rate Test for Ship Antifouling Compositions. Joint Tech. Panel on the Leaching-Rate Test of the Marine Corrosion Subcommittee of the Corrosion Comm. J. Iron Steel Inst. (London): 5 pp. (Aug., 1946); Chem. Abs., 40, 6398 (1946) Nov. 10.

In compounds containing cupric oxide only a steady loss of 10 micrograms per sq. cm, per day is effective in preventing fouling. This value is the critical leaching rate for copper. The critical leaching rates for other antifouling poisons are not yet well defined.

Plastic Coating Inside Surface of Drill Pipe to Combat Corrosion Fatigue Failures. L. E. TRISHMAN,

Spang-Chalfant, Pet. Eng., 18, 2, 194 (1946) Nov.

Laboratory tests on protective methods against corrosion fatigue failures in drill pipes indicate that only an air-drying phenolic and a baking-type phenolic base plastic coating are entirely satisfactory. The phenolic base plastic coating was found to be chemically inert except to hot concentrated alkali, resistant to heat up to 400° F., abrasion, oil, chipping, and cold 1.2% alkali. Field tests conducted on coated and uncoated pipes, results of which are not yet complete. Sodium chromate, when used in drilling mud, was found effective in checking corrosion, but field tests to date have not been conclusive as to its benefits. The inhibitive effect is illustrated in a graph showing stress in 1000 psi. vs. million cycles of stress.

Rubber Linings Protect Steel Against Corrosion and Abrasion. O. S. TRUE, U. S. Rubber Co., Prod. Eng., 18, 1, 142-8 (1947) Jan.

Discusses properties of rubber in protecting cast iron and steel surfaces from the corrosive attack of gaseous and liquid chemicals. Discussion includes preparation of metal surfaces and design considerations that facilitate applying rubber linings and coatings to tanks, pipe, fittings, fans and pump impellers. (The necessity of periodic inspection of coated tank cars, etc., is stressed so as to avoid deterioration due to mechanical damage.)—CEC.

Engineering News at a Glance. Steel 119, 15, 120 (1946) Oct. 7.

By dipping metal parts in a solution of cellulose acetate butyrate and hot castor oil, a continuous, tough coating is formed that pro-

tests such parts from corrosion and abrasion in transit and storage, according to Tennessee Eastman Corp., Kingsport, Tenn. Polished mild steel plate coated 0.1 in. thick with the material held in a closed container over water at 100° F. for 150 days with no sign of rust. Dipping operation is simple and the transparent coating permits complete visual inspection and identification of the part. Not only can the coating be stripped easily off parts, but it can be re-used by melting.

—CEC.

Plastic Coatings to Control Metal Corrosion. S. P. WILSON, Cleveland Varnish Products Co., Paper before Jt. Symp. Electrochem. Soc., Am. Chem. Soc. & AICE Cleveland Sections. *Steel*, **119**, 16, 150 + (1946) Oct. 14.

Various types of plastic coatings and problems relating to their use are described. A Navy specification is mentioned.—INCO.

Enameled Screen Gives Best Results in Screening Coke Breeze and Damp Materials. FRED J. GEYER, Blast Furnace and Steel Plant, **34**, 1529-1530 (1946) Dec.

Difficulty with clogging was experienced in screening $\frac{5}{8}$ -in. + 3/16 coke breeze. Several methods for alleviating the difficulty were tried without success. Finally, application of an enamel coating solved the problem. These screens should be useful for screening any damp material.—BLR.

Metallic Film Formation at Low Temperatures. A. GOETZ and others, *Chem. Rev.*, **29**, 481-495 (1946) Dec.

Apparatus and method for condensing thin films from a molecular

beam of pure lead at temperatures down to 14° abs. are described. The electric conductivity of these films was measured during and after exposure to the beam. Onset of conductivity depends upon temperature of the film formation. Changes occurring in the films after exposure are discussed. 15 ref.—BLR.

CONSTRUCTION MATERIAL

A Note on the Interior Surfaces of Milk Pipe Lines in Pasteurization Plants. G. MORGAN & J. BOAG, Dairy Ind., **11**, 760-764 (1946) Oct.

The sections of pipe lines examined were of tinned copper, copper, Monel and stainless steel. The conditions of the surfaces required to maintain maximum plant cleanliness and methods of cleaning are discussed.—INCO.

Special Cast Iron as a Structural Material. M. GUEDRAS, *Mecanique*, **28**, 39-42 (1944); *Chem. Abs.*, **40**, 7118-7119 (1946).

After a general discussion of alloying constituents and their role in graphitization the following properties are discussed as being important in the selection of cast iron for a given use: the resistance to tensile strain, pressure, impact, wear, chemical attack, and to thermal stresses. A cast iron containing 2.5-2.8 percent carbon, 2.25-2.8 percent silicon, 0.8-1.2% manganese, 1-1.2% nickel, and 1-1.2% molybdenum is used with good results in the motor industry. Another cast iron containing 3.9-4.1% carbon, 0.8-1% silicon, 0.6-0.9% manganese, .15-0.2% phosphorus, and as little sulfur as possible is very satisfactory. Tests reported show that the properties are

improved by the admixture of 0.5% each of chromium and molybdenum, since the best resistance to thermal stresses is shown by alloys containing chromium, nickel, molybdenum, and copper. Austenitic cast iron containing greater than 2% chromium is 10-12 times as resistant as ordinary cast iron at 850-900° F. Cast iron containing 14% nickel, 6% copper, and 2% chromium, and a Czechoslovakian product containing 1.0% carbon and 30% chromium show very good resistance to corrosion.

—INCO.

Directory of Materials for the Construction of Chemical Equipment—Chemical Resistance of Constructional Metals and Non-Metals. Chem. Eng., **53**, 11, 110-150 (1946) Nov.

From Chemical Engineering's 12th Report on Materials of Construction. Includes 600 items and 24 reagents. Arrangement is alphabetical, compositions of alloys are given, forms available, manufacturer, and resistance to various chemicals. Second part arranged alphabetically by reagents.—INCO.

Corrosion Resistance of Steel and Cast Iron. A. W. SPITZ, Chem. Eng. **54** 2, 135 (1947).

Data are presented on the corrosion resistance of steel and cast iron to a number of common chemicals. The information given here is intended to serve as a starting point in determining the suitability of iron and steel for process equipment.—CALCO.

Chemical Resistance of Constructional Metals and Non-Metals. Chem. Eng., **53**, 120-150 (1946) Nov.

A list showing applications of

various metallic and non-metallic materials in the handling and transport of some 24 common and troublesome inorganic and organic chemicals with indications of the behavior of the numerous materials towards the chemicals. While the list will have its uses, it is of interest that the compilers add the following note: "Corrosion involves many more variables than this or any other table can possibly recognize. These data should never be construed as anything more than an aid in narrowing the field of materials that are worth investigation."—BNF.

Lined with Corrosion Resistance. Process Inds. Quar., **9**, 3, 6-7 (1946).

Notes on lining of vessels with nickel and other corrosion-resisting sheet materials.—INCO.

Corrosion of Constructional Materials by Sulphur and Sulphides. J. R. WEST, Mellon Inst., Chem. Eng. **53**, 10, 225-226 + (1946) Oct.

In a thorough investigation, instigated by Texas Gulf Sulphur Co., to determine the present state of knowledge on corrosion by sulfur and sulphides, literature was surveyed and information gathered from 135 industrial concerns using and producing constructional materials. Quantitative data are presented on corrosion of various metals in molten sulfur, including Ni-resist, nickel, Inconel, Monel, stainless-steel Types 304, 410 and 430, cast iron, Hastelloy c, "K" Monel, mild steel, copper-manganese alloy, and copper. Text also discusses aluminum, cast iron and carbon steel, ceramics, fused silica, chromium, copper and copper alloys, lead, magnesium, nickel and

nickel alloys, manganese, platinum, silver and silver alloys, 18-8, 25-20, and 27 chromium stainless, in sulfur. The effect of sulphides in solution and sulfur in solution is also discussed. The chart on quantitative corrosion by molten sulfur shows: 1) Ni-resist corrodes 10 times faster than stainless Type 304; copper plus 10% manganese 10 times as fast as Ni-resist, and copper 3000 times as fast as Type 304 stainless; 2) at 500° F. Ni-resist corrodes at 42 times the rate of Type 304; at 565° F. at 264 times the latter; and the relative corrosion rates of nickel and Inconel are 27 to 1 at 665° F.; nickel corrodes 40 times as fast as Type 304 stainless at 690° F.; and at 835° F., Monel corrodes 35 times as fast as Inconel. Platinum reacts with sulfur at very high temperatures during chemical analyses involving ignition, fusion and evaporation.

FUNDAMENTALS

Investigation of the Corrosion Processes Using a Model of Local Galvanic Couples. Part II. Current Distribution & Change of Resistance in Short-Circuited Models. A. I. GOLUBEV & G. V. AKIMOV, *J. Phys. Chem. (USSR)* **20**, 309-314 (1946); *Chem. Abs.*, **40**, 19, 5651 (1946) Oct. 10.

Current-voltage curves are determined for copper and zinc in 3% sodium chloride + 0.06 normal hydrochloric acid + 0.24% hydrogen peroxide. These data and the potential distribution determined in Part I allow the c.d., i, on composite electrodes to be calculated, i has a max. at the copper-zinc boundary and in the majority of the models is greater on anodic than on the cathodic surface.—INCO.

Electrochemical Investigation of the Corrosion of Metals (Iron, Lead) in Acid Media in the Presence of Oxidizing Agents. I. OKNIN, *Zhur. Priklad. Khim.*, **13**, (9/10), 494-504. (In Russian) (1945); *J. Inst. of Metals and Metall. Abs.*, **13**, 321 (1946) Sept.

An electrochemical study was made of the corrosion of iron and lead in acid media containing oxidizing agents. Factors studied were the rate of corrosion, the potential of the corroding metal, the potential of a platinum cathode as a function of cathode c.d., the electrical conductivity of the systems platinum-medium-platinum and corroding metal-medium-corroding metal, and the hydrogen-ion concentration. It is shown that the rate of corrosion of the metal is determined by the magnitude of its potential during corrosion. A theoretical survey of the problem is made.—INCO.

An Electron Diffraction Study of Oxide Films Formed on Alloys of Iron, Cobalt, Nickel and Chromium at High Temperatures. J. W. HICKMAN & E. A. GULBRANSEN, *Westinghouse Electric Corp., Met. Tech.*, **13**, (1946) Oct.; *AIME Tech. Pub.* 2069, 27 pp.

An extension of the work noted above to typical commercial scale-resisting, heat-resisting and magnetic alloys and to alloys for sealing into glass; temperature range covered was 300-700° C. Examples of conclusions are that iron and chromium ions diffuse to surface more readily than the others, that nickel-oxygen and probably cobalt-oxygen never form on surface even in high-content alloys and that, apart from iron and chromium, metals are not

present as simple oxides in the film when they constitute less than 5% of the alloy. The lattice perimeters of the film oxides differed from those determined on the oxide in bulk.—BNF.

Overvoltage in Electrolysis. The Cases of Hydrogen and Oxygen. V. KARPEN, Acad. Sci., Paris, **222**, 541-543 (1946) Mar. 4; 644-666 (1946) Mar. 18; Phys. Abs., **49**, No. 585, 262 (1946) Sept.

Overvoltage phenomena were previously explained on a new theory of contact electro-motive forces and application of it is now made to hydrogen. A double voltameter is described consisting of two cathodes (platinized platinum on platinum and gold on gold) with a common anode, and immersed in a dilute sulphuric acid solution containing hydrogen under atmospheric pressure. A mode of calculation of hydrogen over-voltage is also given for currents of strength just sufficient to indicate the visible evolution of hydrogen. Experiment and theory are found to be in agreement. For the case of oxygen, the described voltameter contains two anodes of platinum and gold as above with a common cathode in a dilute sulphuric acid bath containing oxygen at atmospheric pressure. A formula is given for the overvoltage, and as the current increases an undervoltage is noted and discussed.—INCO.

Theory of the Corrosion of Metals. Part. III.—On the Uniformity of Corrosion. V. S. DANIEL-BEK, Zhur. Fiz. Khim **20**, 6, 567-573 (1946), (in Russian); J. Inst. of Met. & Metall. Abs., **13**, 419 (1946) Dec.

A model of a micro-element was

made in the form of a bimetallic (copper and zinc) plate, the reverse side of which was covered with a layer of insulating material. The plate was put into a vessel filled with one of four electrolytes (0.05 and 0.01 normal potassium chloride and 0.2 and 0.05 normal potassium-chlorate, and served as a partition dividing the vessel into two parts. The surface of the anode (zinc) was provided with a series of holes which enabled the potentials of different parts of the anode surface to be measured. The uniformity of corrosion of a metal increases with rise in the conductivity of the electrolyte and with the polarization of the corroding micro-element.—INCO.

Cathodic Processes in Metallic Corrosion. N. D. TOMASHOV, C. r. Acad. Sci. USSR, **52**, 691-4 (1946).

Cathodic processes in metallic corrosion are studied by an analysis of the following curves: overvoltage of oxygen ionization, concentration polarization, oxygen polarization, hydrogen polarization, and oxygen-hydrogen polarization.

Electro-Chemical Corrosion of Cast Iron Applied to Microscopic Metallography and the Theory of Action of Reagents. L. F. GIRARDET, Assoc. Tech. Fonderie, Journees Fonderie, **1945**, 197-206, 1945.

When a reactive electrolyte covers polished cast iron, the metal is negatively charged and the liquid positively charged so that the difference in potential forms a double layer assuring electrostatic equilibrium between the contiguous surface. Heterogeneity of texture causes the cast iron to consist of anodic nega-

tively charged areas and non-anodic negatively charged areas, as graphite. Above these the double layer is broken and positively charged cations can enter. These are cathodic areas which polarize as the cations from anodic areas discharge. Corrosion is reinforced at points bordering these local currents. Corrosion of anodes stops as cathodes become polarized. If the anodic surfaces are larger, polarization is rapid, action of local couples is buffered and corrosion is general. If cathodic surfaces are larger, polarization is slow and corrosion of anodes intensive so that ferrite or graphite in these areas dissolves completely.—INCO.

Hydrogen Overvoltage as a Factor in the Corrosion of Metallic Couples. T. P. HOAR, *Nature*, **157**, 3987 & 408-409 (1946); *J. Inst. of Met. & Metall. Abs.*, **13**, 322 (1946) Sept.

The results reported by Le Brocq and Cocks (*Nature*, **156**, 1945, 536) are interpreted in terms of potential current diagrams. The usefulness of such constructions is pointed out.—INCO.

Investigation of the Corrosion Processes Using a Model of Local Galvanic Couples. Part I. The Field in the Electrolyte Above Short-Circuited Models Situated in One Plane. G. V. AKIMOV & A. I. GOLUBEV, *J. Phys. Chem. (USSR)* **20**, 303-308 (1946); *Chem. Abs.*, **40**, 19, 5651 (1946) Oct. 10.

A flat horizontal electrode, part copper, part zinc, is kept in 3% sodium chloride + 0.06 normal hydrochloric acid + 0.24% hydrogen peroxide and the potential V over

various spots of the electrode is determined at the metal surface and 1, 2, 10, 20, 30, and 60 mm. above it.—INCO.

GAS AND CONDENSATE WELL CORROSION

Checking Corrosion of Oil Well Pipelines. N. HACKERMAN & D. A. SHOCK, Univ. of Texas. Paper before Am. Chem. Soc., Chicago, Sept. 12, 1946; *Chem Eng.*, **53**, 11, 296 + (1946) Nov.

Corrosive attack by carbon dioxide water and organic acids is erratic. Gas condensate wells were used as a laboratory to study the action of the gas stream on the interior of the pipes through which the gas is produced. From the data gathered, the wells were grouped into three general types, critical, non-corrosive, and intermediate. The addition of a small amount of naphthenic acid formed a protective film which inhibited the attack of organic acid.—INCO.

Tests at Cycling Project Demonstrate Possibilities of New Corrosion Inhibitor. W. H. JUSTICE & E. N. JONES, Paper before Nat. Gas. Assoc. of Am., Quart. Mtg., Dallas, Tex. *Oil & Gas J.*, **45**, 27, 86-87 + (1946) Nov. 9.

Ability to selectively wet steel of casting and tubing without raising pH (which would cause precipitation of calcium and magnesium) and oil solubility were requirements of an inhibitor. Kontol 115 fulfilled them and reduced corrosion to 7% of original rate in field tests. Details of a chemical feeder hookup and corrosion coupon holder are shown. In-

hibitor has residual effect for several days after injection.—INCO.

Some Metallurgical Observations with Respect to Corrosion in Distillate Wells. M. E. HOLMBERG, Phillips Petroleum Co. Corr. 2, 278-286 (1946) Nov.

Factors causing corrosion in ends of tubing are discussed. "Ringworm" corrosion is found near the upset, is not due to turbulence, or change in stress at upset, nor to excess scale. It is eliminated by avoiding changes in structure accompanying upsetting by normalizing the entire length of tube. Corroded couplings are also discussed and structures shown and discussed. Carbon content is not a vital factor, but condition of carbides is. Steel with a well developed pearlitic structure corrodes more slowly than a similar steel with spheroidized structure. Severe corrosion sometimes occurs at the edges of mill scale on the outside surface of a tube. Accelerated corrosion occurs where there is a cross patch pattern, often observed in metal stressed above its yield point, at threaded end of tubing hanger. A "washout" failure is also shown and discussed.—INCO.

The pH of Waters from Gas-Condensate Wells Saturated with Carbon Dioxide at Various Pressures. H. A. CARLSON, Phillips Petroleum Co., Paper before NGAA Corr. Res. Proj. Comm., Dallas, Tex., Oct. 17, 1946; Pet. Eng. 18, 2, 160 + (1946) Nov.

The pH of waters from several gas-condensate wells, saturated with carbon dioxide, was measured at various pressures to determine whether the pH is low enough to

give accelerated corrosion. Four water samples (three gas-condensate well waters and one oil well water) saturated with carbon dioxide at pressures from 20 to 80 psi. at room temperature ranged in pH value from 4.7 at the lowest pressure to 4.1 at the highest. A fifth sample exhibited strong buffer action to carbon dioxide under pressure at a pH of 5.2 due to borate indicated to be present by spectroscopic analysis. The estimated pH at the wellhead can be calculated from the wellhead pressure and the percent carbon dioxide in the gas assuming equilibrium has been reached. Preliminary laboratory colorimetric measurements of pH using a double window Jerguson gauge indicate that the pH can be determined in the field at wellhead pressure by using this type of instrument made of stainless steel.

Corrosion in High-Pressure Gas-Condensate Wells. H. ARTHUR CARLSON, Oil & Gas J., 45, 81-84 (1946) Dec. 21.

Review of literature reveals lack of fundamental data on the effect of certain factors and indicates a definite need for correlation of data. Correlates and summarizes work that has been done so far to aid in planning future work. 10 ref.—BLR.

GENERAL CORROSION

Crack-Heal Mechanism of the Growth of Invisible Films on Metals. Nature, 157, 3996, 732 (1946). J. Inst. of Met. & Metall. Abs., 13, 322 (1946) Sept.

The invisible films formed on unheated iron exposed to air were studied by using a sodium-carbonate-bicarbonate buffer solution to reveal

major discontinuities as rust spots. The primary effect of air-exposure is to heal existing pores and the secondary effect is to introduce new ones, owing to strains introduced on oxidation. In addition to chemical blockage, produced by oxidation at the base of an already existing pore, mechanical blockage may occur anywhere in a pore. The chance of mechanical blockage increases with film thickness, leading to a decrease in the rate of oxidation. The logarithmic film-thickening law may be explained by these considerations.

A Review of the Corrosion Process. G. CORSARO, *Natl. Engr.*, **50**, 537-9 (1946); *Chem. Abs.*, **41**, 1, 80 (1947) Jan. 10.

The theories underlying various types of corrosion are discussed. Protective measures are suggested.—INCO.

Metal Finishing. ADOLPH BREGMAN, *Iron Age*, **159**, 160-165 (1947) Jan. 2.

Discusses economic and technical developments of 1946 and prospects for 1947.—BLR.

Technical Developments of 1946. RICHARD A. MOZER, *Met. Fin.* **45**, 50-55 + (1947) Jan.

General review covering theory; anodizing corrosion prevention; polishing; cleaning; abrasive blasting; pickling; coatings; electroforming and metallizing non-conductors; metal coloring; testing and miscellaneous. 210 ref.—BLR.

Chemical Research and Corrosion Control. DR. VERNON, *Paper*, London Sect., *Soc. Chem. Ind.*, Oct. 7, 1946; *Abs. Chem. & Ind.* **43**, 389 (1946) Oct. 26.

Corrosion research since 1939 by

the Chem. Sec. of the Chem. Res. Lab. (DSIR) is briefly reviewed. The corrosion inhibitive properties of sodium benzoate are discussed. In smaller concentrations, this substance in solution inhibits corrosion produced by tap water and by solutions of ethylene glycol or glycerine. It is also non-detergent to rust already present. As an impregnant, it confers corrosion-preventive properties on wrapping materials under tropical conditions. When volatile, it prevents corrosion in enclosed air spaces.

Universal Photographic Cells. Part I. The Use of a Heat Balance for the Investigation of Corrosion in Gaseous Media. A. M. DUMÉZ, *Métaux Corrosion Usure*, **18**, 50-55 + (1943); *Chem. Abs.*, **40**, 7142 (1946).

Universal photographic cells with various accessories are described and the possibility of their use for the investigation of the corrosion of metals in gases is discussed. The results of oxidation in copper and of an austenitic nickel-chromium alloy in air at constant temperature, and at different rates of heating are reported in curves. These show, e.g., that the rate of oxidation of copper increases sharply at about 800°. The curves showing increase in weight vs. temperature differ in form for different rates of heating, due to the varying permeability of the oxide layer.—INCO.

INHIBITORS

Germicidal Sprays and Prevention of Corrosion. H. L. A. TARR, *Pacific Fisheries Experimental Station*, *Fisheries Res. Board of Canada*,

Progress Report No. 59, of Pacific Coast Stations, June, 1944, 7-9.

Experiments including the germicidal effect and the corrosive action of three sprays used on fishing boats and equipment showed that an effective spray is a 2½% solution of formalin containing a small amount of sodium nitrite as corrosion inhibitor. A 1% sodium hypochlorite solution causes severe corrosion of iron and copper surfaces and the addition of 1% sodium nitrite to neutralize this effect kills the germicidal action of spray. A 5% sodium nitrite plus 1% acetic acid in water causes temporary corrosion of iron surfaces, but the acetic acid soon evaporates and the sodium nitrite checks the corrosion. This solution should not be left long in contact with metals under conditions in which the acid cannot evaporate quickly. The iron acetate which forms when iron surfaces are corroded by a solution such as this is soluble in water, and readily removed while the production resulting from the action of hypochlorites on iron is insoluble in water and difficult to remove.—INCO.

Corrosion of Iron by Water-in-Oil Emulsions. L. C. VERMAN and M. L. KHANNA, *J. Sci. & Ind. Res. (India)*, **4**, 449-50 (1946) *Chem. Abs.*, **40**, 6399 (1946) Nov.

Emulsions of water in mineral lubricating oil led to excessive corrosion in an engine used as a pump. Water is not entirely insoluble in oil; it diffuses through oil films 0.8-3 mm. thick. Experiments on the corrosion of highly polished steel plates dipped in emulsified oils for 250 hrs. at 50°C. showed corrosion could be

stopped by the use of additives such as small quantities of the fatty acid soaps of chromium.

Oleophobic Monolayers. Part I. Films Absorbed from Solution in Non-Polar Liquids. W. C. BIGELOW, D. L. PICKETT & W. A. ZISMAN, *J. of Colloid Sci.* **1**, 513-538 (1946) Dec.

It was found that certain types of polar organic molecules are adsorbed from solutions in non-polar solvents to form well-oriented monolayers on polished solid surfaces. Such monolayers imparted both hydrophobic and oleophobic properties to the polished surfaces of a variety of metallic and non-metallic solids and could be formed from a large variety of solvents. The mechanism of formation of these films is discussed. These films and the information obtained in this study are thought to be applicable to research on oiliness, wear prevention, emulsification, detergency, wetting and the inhibition of rusting steel with polar compounds. 23 ref.—BLR.

A Review of Inhibitors: W. G. IMHOFF, W. G. Imhoff Co., Paper before Wire Assoc. Mtg., San Francisco, June 7, 1946. *Wire & Wire Prod.*, **21**, 6, 447-450 + (1946) June; No. 7, 520-523 + (1946) July; No. 8, 598-599 + (1946) Aug.; No. 9, 621-623 (1946) Sept.

In reviewing this field of pickling, early records of cleaning and pickling, inhibitors and various materials mentioned as addition agents, foam compounds, classification, sulfuric acid manufacture and inhibitor theories are discussed. Record of inhibitor patents from 1883-1946 is given. Bibliography.—INCO.

METAL FAILURE

Contribution to the Question of Changes in Materials Under Fatigue Stress. (Brass, Aluminum, Duralumin. Nickel-Chromium-Iron Alloy, Steels). A. KARIUS, *Metallwirtschaft*, **23**, 419-434 (1944) *J. of Inst. of Met. & Metall. Abs.*, **13**, 318 (1946) Sept.

Experiments were carried out on specimens of brass, aluminum, duralumin, 19% iron-25% nickel-chromium alloy, and various steels to determine the influence of fatigue on the elastic modulus and damping capacity. Plain and notched test-pieces were subjected to alternating-bend tests in a Schenck fatigue-testing machine and, after various numbers of cycles, the alterations in damping capacity and elastic modulus were determined in a Forster machine. Initially there is a sharp increase in damping capacity and a corresponding decrease in elastic modulus due to cold working; these effects almost vanish with a slight increase in stress and duration of test but recur, as a result of the formation of microscopic cracks shortly before the onset of fracture. Preliminary static or dynamic stressing causes a reduction in damping and modulus changes by fatigue testing, but high preliminary stressing brings about a reversal of this effect.—INCO.

The Effects of Microstructure on the Mechanical Properties of Steel. J. H. HOLLOMAN, L. D. JAFFA, D. E. MCCARTHY & M. R. NORTON, *Watertown Arsenal, ASM Preprint*, **25**, 39 pp. (1946).

The effects of microstructure on the tensile impact and fatigue properties of NE 8735 and SAE 3135 steels were investigated. Specimens of the NE 8735 steel were first heat

treated to produce various As-quenched structures, namely, martensite, martensite plus ferrite and pearlite, and martensite plus bainite, and then tempered before testing. Specimens of the SAE 3135 steel were embrittled various amounts by heating at 450° C. for different periods of time after tempering at a higher temperature. Except for the reduction of area (and fracture strength), the tensile properties are unaffected by changes in structure. The impact properties, which reflect the fracture stress of small strains, are very dependent upon structure. The fatigue properties as determined in tests in R. R. Moore machines are affected to a limited extent by changes in structure. The properties of tempered martensite steels are superior to those of steel having other structures.—INCO.

Investigation of the Cavitation Phenomena, Parts I and II. E. BRANDENBERGER & P. DE HALLER, *Schweiz. Arch. Angew. Wiss. Tech.*, **10**, 11, 331-341; No. 12, 379-386, (1944); *J. Inst. of Met. & Metall. Abs.*, **13**, 297-8 (1946) Aug.

The effects of the speed of impact, jet area and temperature, and speed of water jet on the erosion of a mild carbon steel were studied in a specially-designed apparatus. The nature of the erosion was studied in an impact-wave apparatus and was supplemented by mechanical, metallographic, and x-ray examinations. A study, by back-reflection photographs, of the changes in the crystal structure at the surfaces of the specimen exposed to erosion showed that the crystals gradually break up into smaller units and finally develop small cracks. It is believed

that the process of fracturing in erosion tests is different from that of the static or fatigue fracture, owing to the role the cleavage of crystals assumes in this case.—INCO.

Corrosion of Light-Metal Screws in Pressed Phenol Resin. K. GEIER & L. RESCHKE, *Electrotech. Z.*, **65**, 76-77 (1944); *Chem. Abs.*, **40**, 6398 (1946).

Experiments were carried out for the purpose of determining the cause of the corrosion of aluminum-magnesium-silicon screws in pressed phenol resin containing wood meal or cellulose as filler. Anodically oxidized screws subsequently treated with distilled water or phenol resin varnish or greased with Stauffer grease were not corroded. The corrosion appeared to be caused by condensed moisture (sweating) and not by any action of the resin.—INCO.

Comparison of Various Structural Alloy Steels by Means of Static Notch-Bar Tensile Test. G. SACHS, L. J. EBERT & W. F. BROWN, JR., *Met. Technol.* **13**, T.P. 2110, 17 pages (1946) Dec.

Various steels or heats of the same steel treated to yield identical properties in the conventional tensile test may exhibit widely different service performance, except for the impact test, particularly at low temperatures. Laboratory tests in general have failed to yield clearly defined criteria for such differences. Authors have applied their static notch-bar tensile test to this problem with excellent success, since large differences were revealed where none were apparent when other testing methods were used. Test results are shown graphically. 11 ref.—BLR.

Pump Cavitation. B. R. WALSH, Gulf Res. & Development Co. Paper, ASME, Tulsa, Oct. 7-9, 1946; *Oil & Gas. J.*, **45**, 23, 99 (1946) Oct. 12.

Remedies for cavitation are classified as: 1) Reduction of pump entry loss to absolute minimum, by reduction of peripheral speed or clearance volume, use of side pockets and incorporation of pickup blades or ports and enlargement of inlet passage with elimination of turns and bends; 2) Increase of pressure available at pump inlet by reduction of inlet line loss, increase of liquid supply head, installation of centrifugal booster (for positive-displacement pumps), pressurized supply tank, elimination of entrained air (and dissolved air, if feasible).—INCO.

Influence of Shot Peening on Fatigue Strength of 14ST Alloy. C. B. GLEASON, *Iron Age*, **159**, 62-64 (1947) Jan. 9.

Results of an investigation to determine the effect of shot peening on the fatigue strength of 14ST aluminum alloy are discussed. Tests on unnotched specimens indicated possibility of increases in life of as much as 80 times that of unpeened material, while notched specimens showed more than 32 percent improvement in fatigue strength.—BLR.

Hydrogen in Metals. A. PORTEVIN, *Met. Prog.*, **50**, 1206-1208 (1946) Dec.

Based on the researches of Chau-dron in France in recent years, author points out that effect of hydrogen on metals depends on whether the gas is intergranular, intercrystalline or interatomic. As an example, a table shows the various effects on the properties of iron.—BNF.

Summary of the Rheological Properties of Matter Under High Pressure. P. W. BRIDGMAN, Paper, Soc. of Rheology, New York, Nov. 1, 1946; abs. Rheology Bull. 17, 3, 6 (1946) Nov.

The author's own experiments on the viscous flow of liquids and plastic deformation of solids under high pressure are reviewed. The viscosity of ordinary organic liquids was found to increase under pressure at continually accelerated rates, the magnitude of the effect varying enormously from liquid to liquid. Solids such as steel exhibit an increased ductility under pressure and a raised elastic limit although the latter is not so great as the rise in ductility. Both the ductility and work-hardening increase approximately linearly with pressure. Phenomena such as flow stress and shearing under pressure differ from previous theories as to the behavior of the material. A brief mathematical discussion of the paper is included.

Study of the Damaging Effect of Fatigue Stressing on SAE X4130 Steel. J. A. BENNETT, J. of Res., Nat. Bur. of Standards, Research Paper RP 1733, 37, 2, 123-139 (1946) Aug.

A study of notched specimens for comparison with results of smooth specimens. Special modifications of the R. R. Moore machines and traveling microscope were used. Criteria of failure was a deflection of 0.005 mm. Tests were conducted to determine the sulfur-nitrogen curve and the fatigue limit. Specimens were first stressed for a predetermined number of cycles at the four chosen stresses, then the stress was changed and the number of cycles to failure

determined. Conclusions as to fatigue damage occurring prior to the start of cracking are given. Damage occurring at one stress is determined by measurement at another, increasing damage decreases the fatigue limit, improvement due to understressing can be measured the same way as that of overstressing. Smooth, notched or cracked specimens show the same ratio. Number of cracks increases as the test stress is raised above the fatigue limit, a small crack will decrease the fatigue limit. Diagram of apparatus and number of charts and graphs.—INCO.

Grain Boundaries in Metals. P. J. E. FORSYTH, G. J. METCALFE, R. KING, & B. CHALMERS. Nature, 158, 875-876 (1946) Dec. 14.

Theory of structure of these boundaries is discussed. Photomicrographs of copper-beryllium alloys and of an aluminum-magnesium alloy illustrate differences in the way in which precipitation occurs. Also discusses the formation of boundary grooves on polished metal surfaces at elevated temperatures.—BLR.

Anodic Corrosion of Brass. J. M. BIALOSKY, Ill. Inst. of Technol., Corr. & Mat. Prot. 4, 1, 15-16 (1947) Jan., Feb.

A series of experiments have been performed using Muntz metal, Naval brass, arsenical Muntz and arsenical Naval brass with applied anodic current in various aqueous solutions at room temperature to determine the dezincification characteristics of these alloys. The results indicate that arsenical Muntz and arsenical Naval brass resist this type of attack and that Naval brass is more

resistant than Muntz metal under the conditions explored. The initial dezincification occurs in the beta phase and attack of the alpha phase follows. The dezincification reaction which was produced in these tests must have been due to selective attack of the zinc rather than by the redeposition of copper, which could not plate out on the anode of the cells.—CEC.

Intergranular Corrosion Determination. H. KIRTCHIK, *Iron Age*, **159**, No. 10, 67-70 (1947) Mar. 6.

A cyclic test for this type of corrosion was developed in an effort to evaluate factors responsible for supercharger nozzle-box failures. Illustration.—AER.

The Structure of Scale and the Mechanism of High Temperature Oxidation of Steel. V. I. ARKHAROV, *Bull. de l'Academie des Sci. de l'Ures, Classe des Sci. Techn.*, **1946**, 3, 453-457.

Structure of scale, especially on iron and steel, as a preliminary to the further development of heat resisting steels was studied. High temperature oxidation as a diffusion problem, data on the different layers of iron scale based on X-ray analysis, significance of iron-oxygen zone in iron scale, types of textures in iron scale, oxidation of steel vs. nickel, cobalt and chromium, and general principle governing the heat resistance of steel are discussed. 24 references. This article was preceded by one in same journal **1946**, 1, 127-132.—INCO.

Graphitic Corrosion of Cast Iron. LAURIE M. LEEDOM, *J. Am. Water Works Assoc.*, **38**, 1392-1397 (1946) Dec.

Explains mechanism of graphitic corrosion, and recommends use of alloyed metal for valves to minimize the corrosion.—BLR.

PIPE CORROSION

A New Stray Current Control System. *Pipe Line News*, **18**, 11, 24 (1946) Nov.

This system, announced by the Cook Research Laboratories, is said to prevent damaging effects caused by electrolytic action on underground pipe installations. The system is described as a current and voltage-sensitive device operating jointly on a high current contactor which is activated by the current and voltage-sensitive device, the functioning of which depends on the amount of current or potential present in the pipe.

Underground Corrosion. KIRK H. LOGAN. 312 pages. 1945. Nat. Bur. of Standards, Washington, D. C.

An assembly of the results of the National Bureau of Standards investigations of underground corrosion, which began in 1922. Discusses fundamental causes and processes. Presents results for different metals and alloys and evaluates various coatings for corrosion protection. Describes several methods for testing soils and coatings and discusses their usefulness.—BLR.

Anaerobic Corrosion of Iron in Soil With Particular Consideration of the Soil Redox Potential as an Indicator of Corrosiveness. R. L. STARKEY & K. M. WIGHT, *AGA Proc.* 25th Ann. Mtg. 307-412 (1945).

The results of the AGA Iron Cor. Res. Proj. carried out in the Dept.

of Microbiology of the N. J. Agric. Exp. Sta. in Rutgers Univ. from Sept. 1941 to July 1945 are summarized. A detailed discussion is presented on the anaerobic corrosion of iron in soil, data being presented on the characteristics of corroded iron and steel surfaces, the origin of sulfide in soil, characteristics of the bacteria causing anaerobic corrosion, the importance of sulfate reduction, mechanism of the process of microbiological anaerobic iron corrosion, evidence for the electrochemical theory of anaerobic corrosion, the utilization of hydrogen and the reduction of sulfate by bacteria, detection of microbiological anaerobic iron corrosion in soils, the oxidation-reduction potential, field tests of the degrees of correlation between severity of corrosion and the soil redox potential and other soil characteristics, and the resistance of some pipe wrapping materials, comprising a cellulose acetate sheet, a sheet of fabric or asbestos, and wax containing ferric oxide impregnating both of these and holding them together as a thin wrapper, to decomposition in soil. 203 ref.

Graphite Formation in Cast Iron and Its Tempering by Graphitization. M. GUEDRAS, *Rev. Ind. Minerals*, **1944** 47-66 *Chem. Abs.*, **40**, 7119, (1946).

A review, covering the role of graphitization in cast iron; the historical development of the iron-carbon phase diagram; the formation of the various constituents of the structure of cast iron; mechanical and thermal processes of graphite refining; discussion of the theory of Piwowarsky; and the chemical constituents of cast iron and their role in tempering.

REFINERY CORROSION

Corrosion of Refinery Equipment. E. E. KERNS, Standard Oil Company, (Ohio); Paper, ASME, Tulsa (Oct. 7-9, 1946); abstr. *Oil & Gas J.* **45**, 23, 96 (1946) Oct. 12.

The effects of hydrochloric acid evolution, hydrogen sulfide and mercaptan sulfur, total chloride content and total sulfur content on the corrosiveness of crudes is discussed. At high temperatures sulfur corrosion is believed to be the controlling factor and even at low temperatures nonferrous alloys, such as red brass or other copper alloys, are greatly affected by it. Total chloride content is important as to the tendency of the crude to plug heat-exchanger tubes and the inorganic solid content of the residual product (coke, heavy fuel oil, or asphalt) can be predicted from it. Desalting and ammonia neutralization, and corrosion-resistant material for exchanger tubes, condenser and cooler tubes, and towers for various conditions are discussed.

Special Materials Solved Corrosion Problems at Oak Ridge. R. J. SCHRADER AND A. DE HAAN, *Chem. Eng.*, **53**, 96-101 (1946) Nov.

Production intricacies of materials for use in atomic bombs demand the most resistant materials of construction. Elimination of corrosion is a "must" not only for the prevention of equipment deterioration but for minimizing uranium losses. Many procedures developed especially for use at the electromagnetic separation plant of Clinton Engineer Works called for development of new alloys and non-metallic materials, and in addition special fabrication techniques.—GPC.

SURFACE TREATMENT

Formation and Application of Phosphate Coatings. VAN M. DARSEY AND WALTER R. CAVANAUGH, Parker Rust-Proof Co., Electrochem. Soc., Preprint 91-1 (1946).

The first commercial use of phosphate coatings was for the protection of iron and steel from corrosion and followed the proposal of Coslett of England in 1908 to treat iron and steel articles in a hot dilute phosphoric acid solution with a control agent such as iron filings. This process, later modified and considerably improved, contains the fundamental principle on which the more recent methods of phosphating are based. It required from two to two and one-half hours for production of phosphate coatings by the Coslett process, which seriously restricted its use. The use of metal accelerators and suitable oxidizing agents in the phosphating solution expedited the coating formation and made possible the production of paint base coatings on metals within two to five minutes. Combining spray application with such accelerated phosphate solutions containing an oxidizing agent, further reduced the coating time to as low as two to ten seconds. Heavy corrosion-preventive type coatings are usually produced by immersion application and require from thirty minutes to one hour to produce. The phosphate coatings of non-ferrous metals such as zinc, aluminum and their alloys is increasing in commercial use to prevent corrosion and increase the adhesion of applied paint coatings over such surfaces. In recent years phosphate coating of bearing surfaces has been used extensively to retard wear. A most recent industrial application

of phosphate coating steel is to facilitate drawing. This application has been in industrial use in Europe for several years; it has gained industrial application in America since 1941.

A Comparison of Cleaning Processes for Die Casting. CARL VON SONNENBERG, Die Castings, **4**, 55+ (1946) Nov.

Discusses hot tank cleaning; cold tank cleaning; electrocleaning; mechanical washing machines; vapor degreasing, and organic solvents.—BLR.

Metal Cleaning, Finishing, Protection. Met. Prog., **50**, 1061-1076+ (1946) Nov.

Group of papers organized by Adolph Bregman includes: Postwar Metal Finishing, Adolph Bregman; Principles of Metal Cleaning, Jay C. Harris; Postwar Metal Cleaning Methods, Lionel De Waltoff; War-time Electroplating, George B. Hogaboom; Plating on Plastics, Harold Narcus; Electro-polishing in Postwar Finishing, Charles L. Faust; Polishing and Buffing, Henry L. Kellner; Recent Publications on the Testing of Metallic Finishes, Myron B. Diggin and Otto Kardos (includes 27 ref.); Postwar Paints and Painting Methods, E. A. Zahn; and Postwar Organic Finishes, Gustave Klinkenstein.—BLR.

Controlled Chemical Cleaning. ROBERT V. GARDNER, West. Mach. and Steel World, **37**, 104-107+ (1946) Oct.

Describes hot tank cleaning; cold tank cleaning; electrocleaning.—BLR.

Survey of the Steel Corrosion Problem. A. W. METCALF, Beama J., **53**, 83-85 (1946) March; Corr. and Mat. Prot., **3**, 6, 20 (1946) June-July.

Deals with economic considerations, methods of cleaning metal surface before painting, obtaining a good bonding layer before painting, metal spraying, and other methods for preventing rusting of steel.
—INCO.

Structure Changes of Metals by Cold Working (According to Electron Interference Studies). W. KRANERT AND H. RAETHER, Ann. Physik, **43**, 520-537 (1943); Chem. Abs., **40**, 7116 (1946).

Effects of polishing, stamping, and rolling copper and gold single-crystals were studied by electron diffraction. After working, the structure of a massive single crystal was studied successively at various depths reached by removing thin layers by means of orthophosphoric acid. The outer surface, to a depth of about 10 A., appears to be a quasiliquid, or finest crystallization layer. Gradually with increasing depth a normal crystalline condition occurs, at about 1000 A., and finally at a few under the original surface, the undisturbed single crystal is reached. Similar variations could be followed in a thin single crystal after gradually increased amounts of working. Precautions were required to avoid the effects of thin fine-crystalline layers of oxide on copper, iron, and nickel.
—INCO.

Determination of the Boundaries of Structural Elements in Metallographic Analysis. S. A. SALT'YKOV, Zavodskaya Lab., **12**, 79-88 (1946); Chem. Abs., **40**, 7112-7113 (1946).

A method is described that can be used to determine with a sufficient accuracy, rapidly, simply, and without any special instruments the dimensions of the various elements in the microstructure of polished sections of metals and alloys. The method is of importance in the study of intraphase transformations taking place at the boundaries of the various phases and is the first step in the formulation of quantitative metallography in investigations of the space structure of metals and alloys, on the basis of results obtained in studies of their surfaces. Seven references.—INCO.

Phosphate Processes as a Pre-Treatment for Metal Finishing. H. A. HOLDEN, Paper before Ann. Gen. Mtg., of the Sheet & Strip Metal Users Tech. Assoc., London, (July 15; 1946); Sheet Met. Ind., **23**, 232, 1539-46 (1946) Aug.

A general survey of the phosphate process as a pretreatment for metal finishing is presented. Phosphate coatings have no high corrosion-resistant properties unless combined with paint, lacquer, or organic finish and then, only if the underlying metal has been thoroughly cleaned. The process can be classified into two main groups: 1) 30-60 minutes, the long process for small articles; and, 2) 7 seconds to 10 minutes, the accelerated process for base painting, enameling or lacquering. Widest application is in the treatment of ferrous surfaces. A new use has been for zinc surfaces. Four basic operations involved: 1) cleaning; 2) phosphating; 3) rinsing; and 4) drying. Illustrated by photographs.—INCO.

The Effect of Different Methods of Pretreating Iron and Steel Before Painting. F. FANCUTT, Iron & Steel Inst., Corr. Comm., Paper 17, (1946); Iron & Steel Inst., Special Report 31, 75 pp., (1946).

Results of tests are reported on: effect of weathering, indoor storage, washing procedure after pickling, variations and different methods of pretreating surface, of phosphoric acid washes, weathering to descale, etc., on durability of paint applied to ingot iron, wrought iron, mild steel and copper-bearing mild steel. The rate of breakdown of paint applied to a clean, rust-free, scale-free surface appears to be mainly a function of the paint itself. Life of paint applied to a steel surface not in the ideal condition, however, is influenced by the type of steel, nature of acid used, and almost overwhelming by the surface condition. Spray-applied films were heavier and consequently more durable than brushed ones. Full data are tabulated.
—INCO.

WATER CORROSION

Corrosion Control in Potable Water Systems. R. ELIAASEN, Water & Sewage Works, Ref. & Data Sect., 93, R-163-R-165 (1946).

The use of sodium silicate, hexametaphosphate, sodium septaphosphate and other poly phosphates for controlling corrosion of ferrous metals is described. A table showing the initial and final chemical doses, residuals, and pH value (maximum and minimum) of the treated water is given.

Corrosion and the Formation of Protective Coatings in Water Practice. Vol. II. L. W. HASSE, Book, 1943, 251 pp. Published by Verlag Chemie, G.m.b.H., Berlin. (German title, Werkstoffzerstörung und Schutzschichtbildung im Wasserfach. Teil II).

Applicability of materials for cold water (including ferrous and non-ferrous metals; metallic coatings; non-metals and non-metallic coatings). Composition of water in relation to the destructive action of hot water. Formation of protective coatings in hot water in relation to water treatment. Applicability of various materials for hot water (details as for cold water above).—BNF.

Cathodic Protection of Steel Water Tanks Using Aluminum Anodes.

L. P. SUBRABIN AND R. B. MEARS, AIEE Preprint, New York City, (Jan. 27-31, 1947); Abstr. Elec. Eng. 66, 1, 89, (1947) Jan.

Advantages of aluminum anodes for cathodic protection of steel water tanks over others include: 1) the loss of weight per ampere hour is, in agreement with theory, one-third that with iron; 2) they develop a more uniform attack than steel or stainless steel; and 3) the corrosion products, white or colorless, adhere to the anodes, and do not discolor or contaminate the water. Anodes of several aluminum base alloys have proved satisfactory. However, anodes of aluminum-copper alloys (such as 17S-T or 24S-T) appear to be superior to anodes of unalloyed aluminum (2S) or to aluminum-zinc alloy anodes in installations where current is supplied from an external source.

Corrosion of Yellow Brass Pipes in Domestic Hot-Water Systems—A Metallographic Study. E. P. POLUSHKIN AND HENRY L. SHULDENER, *Corr.* **2**, 1-19 (1946) Mar.

Describes the results of microscopic examination of a series of brass pipes removed from apartment and office buildings. They were selected as typical of approximately 400 specimens obtained over a period of five years. A part of the investigation is reported in this paper and includes a brief history of the pipes, a description of their inside surface and micro-structure, and a study of the effects of corrosion, with particular reference to the structural aspects of local and selective dezincification. 21 ref.—BLR.

Condenser Corrosion Is Reduced. *Chem. Eng. News*, **25**: 48 (1947) Jan. 6.

The use of "Flowrites," metal belled end inserts with very thin fiber sleeves shrunk on the outside, which swell in contact with water to form tight seals even in seriously corroded tubes is discussed.

Recent Developments on Corrosion Control. S. T. POWELL, H. E. BACON AND J. R. LILL, *J. Am. Water Works Assoc.*, **38**, 823; (1946) July; *Metals Rev.*, **19**, 8, 9 (1946) Aug.

Calcium carbonate scale and control of temperature effects; control of saturation index; cold water de-aeration equipment.—INCO.

Study of Copper Alloys in Sulphur, Water. Review by D. P. THORNTON, JR., from "A Study of the Corrosion of Copper Alloy Condenser Tubes," by N. W. MITCHELL, *Pet. Proc.* **1**, 176 (1946) Nov.

Reviews primary causes of corrosion. Results of corrosion as they are visible on the metal are described. Hitherto unpublished data secured from extensive corrosion tests are tabulated, which indicate the comparative resistance of the various alloys to attack by sulphur and water.—BLR.

Scales in Oil-Producing Equipment—Their Occurrence and Causes. L. C. CASE, *Gulf Oil Corp., Oil & Gas J.*, **45**, 21, 76-77 (1946) Sept. 28.

Scale precipitation results from two main causes: 1) supersaturation; and 2) mingling of two unlike waters. Oil field scales may be classed chemically as either sulphate or carbonate. Simple chemical tests are given for identification. Types of scale and the area where they are usually found as well as analysis of scale and water are tabulated. Bibliography.—INCO.

Control Program Insures Follow-up on Prescribed Plant Water Treatment. D. P. THORNTON, JR., *Pet. Proc.* **1**, 181-184 (1946) Nov.

Full value to the refinery and natural gasoline plant of the prescribed chemical treatment for boiler feed-water and cooling water is frequently lost through failure to consistently carry out the various treating steps. A plant control program is a means to overcome this difficulty. The organization of such a program is described. Responsibility for the plant water treatment should be placed with the control program supervisor, and operators should be trained in their functions in the treating program. Regular check-ups should be made on both raw water

and the treated water after use, and these supplemented by more complete laboratory analyses, to determine promptly when changes in the treatment are required and the type of equipment necessary.—GPC.

Corrosiveness of Water to Metals.

I. Theory. T. R. CAMP, J. New England Water Works Assoc. **60**: 188-216 (1946); Chem. Abs. **40**: 6397 (1946).

The electrochemical theory of corrosion is developed for practical application. The theory is first studied as to corrosion reactions and the conditions upon which corrosiveness of a water depends. Several types of anodic reactions are given with formulas as well as cathodic reactions. Thermodynamic equilibrium is also discussed and a formula by which corrosiveness of any metal in aqueous solution can be determined. An eight-page table shows standard oxidation potentials at 25° C. of some half-cell reactions to be considered in corrosion of metals in water. Several examples of application of the theory are detailed and the formation and value of protective coatings briefly outlined.

Corrosiveness of Water to Metals.

II. Practical Application of the Theory. T. R. CAMP, J. New England Water Works Assoc., **60**, 282-293 (1946) Chem. Abs., **40**, 7141 (1946).

Following the explanation of corrosion activity in water in terms of half-cell reactions, an effort is made to apply the principle in a practical way. The corrosion of iron, lead, copper, and brass is studied in particular. The principle anodic and cathodic reactions with each, are given, and in each case corrective

treatment is suggested. No reactions with negative ions of organic acids, save carbonic, are listed. There may be other types of corrosion that this theory will explain.—INCO.

Problems of Automotive Cooling System Corrosion Inhibition. D. H. GREEN AND R. A. WILLIHNGANZ, Paper, ACS, Electrochem. Soc. and A. I. Ch. E. Symposium on Corrosion and Coatings, Cleveland; abstr. Steel, **119**, No. 16, 168 (1946) Oct.

Corrosion inhibitors effective in automotive cooling systems are of two types, alkaline buffering materials such as amines and borates and film forming materials such as oils, phosphates, chromates, nitrites and silicates. Best known performance can be obtained with a combination of two types.

Corrosion Control (in water-mains) with Sodium Hexametaphosphate. P. E. PALLO, J. Am. Water Works Assoc., **38**, 499-510 (1946); Brit. Abs., **BIII**, 188 (1946) Aug.

The rate of corrosion of black iron pipe by water treated with 2 ppm of hexametaphosphate (I) was followed by measuring the decrease in oxygen and increase in iron contents of the water after passing through the pipe, overall loss in weight of the pipe, loss of head, and tuberculation of the inner pipe surface. The rate of flow (y) had a definite influence on all these measures of corrosion, and a critical (y) corresponding with a maximum rate of corrosion was indicated.—INCO.

Cathodic Protection as a Corrosion Control Method Applied to Steel Surfaces Submerged in Water.

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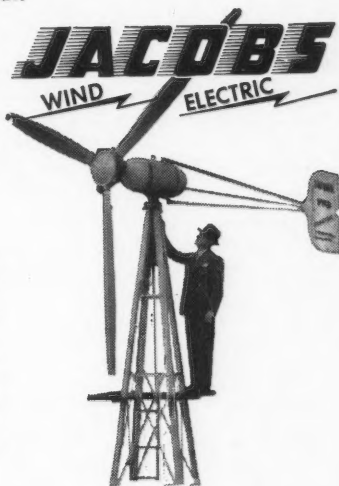
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L. P. SUDRABIN, *Electro Rust-Proofing* Corp. Corr. 2: 175-87 (1946) Oct.

The history of the development of cathodic protection is given briefly. Protective current density requirements can be rationalized from the proper interpretation of dissolved oxygen concentration and scale depositing tendencies of the water, nature of the surface coating, the effectiveness of a barrier layer, the velocity and the temperature. Operating conditions which influence any of these factors must be interpreted properly to apply cathodic protection most effectively. Often surface coatings used in conjunction with cathodic protection provides the most effective over-all corrosion control. Operating limitations encountered with non-sacrificial anodes encourage the use of sacrificial anodes, aluminum appearing to be the most promising. Where ice is encountered, adequate electrode stock should be provided to last during a "corroding season." Galvanic anodes seem to be

feasible where the specific resistance of a water and the current requirements are low. Cathodic protection will be effective if an adequate current flow is properly distributed over the submerged surfaces.


The Crystal Structure at Room Temperature of Eight Forged Heat-Resisting Alloys. J. H. KITTEL, NACE Tech. Note 1102 (1946) July.

Crystal structures of eight forged alloys S 816, S 590, Gamma Columbium, Hastelloy B, 16-25-6, 19-9 DL, Nimonic 80, and N 155 (low carbon)—were determined by X-ray diffraction methods to measure their suitability for high temperature use in gas turbines and jet propulsion engines. The predominant phase in each alloy was found to be a solid solution of the chief alloying elements. The crystal structure of the solid solution is the face-centered cubic type. Alloys S 816, S 590, and Gamma Columbium, which contained the largest percentages of columbium, were found to show diffraction lines from a second phase that is believed to be columbium carbide.—AER.

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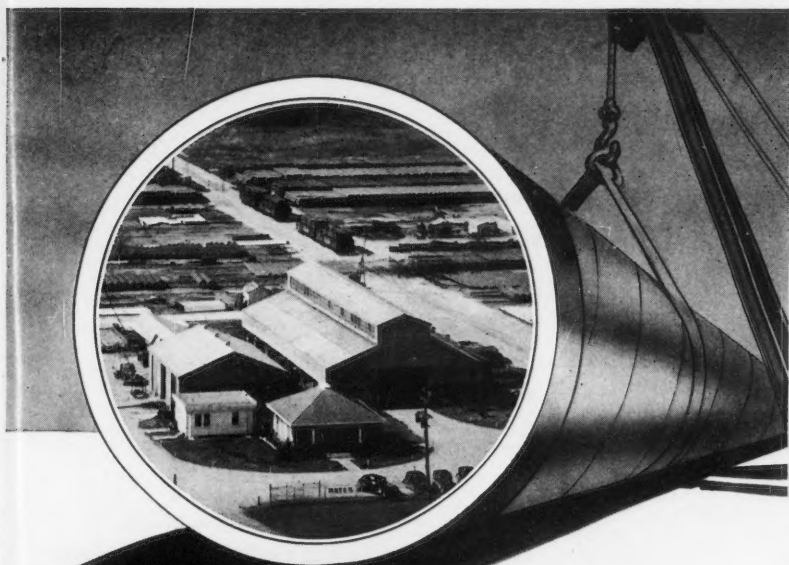
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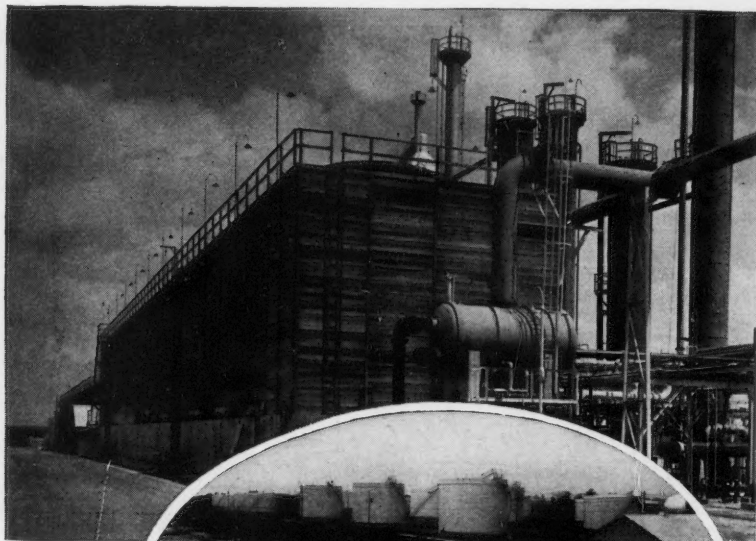
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